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November 13, 2015

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Via Electronic Delivery

Re: Lower Passaic River Study Area (LPRSA)-Exposure Depth/Zone Dispute Resolution
(1) Dispute Resolution Statement
(2) Response to Region 2's October 23, 2015 letter
May 2007 Administrative Agreement and Order on Consent for Remedial Investigation/Feasibility Study – CERCLA Docket No. 02-2007-2009 (AOC)

Dear Ms. Vaughn:

The Lower Passaic River Cooperating Parties Group (CPG) is delivering its (1) Dispute Resolution Statement as part of the CPG's June 12, 2015 invocation of dispute resolution pursuant to paragraph 64 of the May 2007 Administrative Order on Consent and (2) responding to USEPA Region 2's (Region 2) October 23, 2015 letter.

Region 2 has failed to provide any substantive and cogent basis for denying the use of an exposure zone as shallow as 2 cm. The Region's arguments have continued, throughout the nearly 2 years of this issue to be (1) generalized, (2) largely based on assertions of a technically unsupportable and vague allegation of "uncertainty", (3) a scientifically insupportable reliance on partial and/or incorrect information or (4) more recently, an assertion that data collection (which the Region initially invited) would take too long or be too complicated. This has been true since the dispute began with the Region's June 1, 2015 letter and continues with its recent letter on October 23, 2015. Additional hurdles have been presented with Region 2's positions:

- The Region's May 2014 expert paper prepared by a contractor to CDM-Smith was incomplete and severely flawed because it specifically cited maximum burrowing depths when the vast majority of benthic invertebrates were shown to reside within a few centimeters of the surface.
- The Region is either ignoring or contradicting the results of its own 2014 FFS model when it states that the model cannot reliably predict concentrations for intervals of less than 15 cm.
- The Region has inexplicably changed its position on a 2 cm exposure zone as evidenced by its May 1993 OU 2 Scope of Work.

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- The Region has been reluctant if not unwilling to meet with the CPG and have meaningful and substantive exchange on this matter – it has avoided meeting on this issue with the CPG since February 2015.

The CPG has prepared a Dispute Resolution Statement on this matter, as it relates to comments and assertions made by Region 2 in its June 1, 2015 letter and subsequent correspondence on the findings of the CPG regarding the exposure depth or zone (hereafter exposure zone or EZ) issue for the 17-mile Lower Passaic River Study Area (LPRSA). The issue of what is an appropriate exposure zone has been discussed at two meetings between Region 2 and the CPG in February 2014 and February 2015. Following the February 2014 meeting, the CPG provided additional information on the matter (including site specific data) at the request of Region 2 in a letter and attachments dated February 19, 2014. The Region did not provide a response to that letter and did not engage in further discussions with the CPG on this matter for a year - until February 2015. Nearly four months after the February 2015 meeting, Region 2 provided on June 1, 2015 its comments and assertions on the matter of a LPRSA exposure zone. In that letter, the Region suggested that additional sampling could be conducted to resolve the differences between the Region and CPG. Additional correspondence on this matter was received by the CPG by way of the Region's letters dated June 25, 2015 and July 9, 2015.

As a result of the Region's June 1, 2015 letter, the CPG invoked dispute resolution on June 12, 2015; this letter was acknowledged by the Region on June 25, 2015. The CPG sent a third letter on July 2, 2015 requesting the information that the Region had used to make its determinations; the Region responded to this request on July 9, 2015.

Additionally, on August 18 2015, CPG contacted the Region to discuss at the earliest opportunity the development of a sampling program that the Region invited in its previous correspondence. The CPG provided the Region an overview of a proposed sampling plan in advance of the August 26, 2015 teleconference. The CPG agreed to provide a more formal proposal in the form of draft Quality Assurance Project Plan (QAPP) worksheets and it was agreed that the Region and CPG would continue discussions. The CPG provided draft QAPP worksheets for a proposed sampling program on September 17, 2015 to support the development of site-specific exposure zone(s); no further response was received from the Region. On October 5, the CPG contacted the Region by email to inquire on the status of the CPG's proposed EZ sampling program. The Region and the CPG agreed to conduct a call on October 8; the CPG would characterize the call as cordial but generally uninformative on the part of Region 2 as to specific technical issues with the CPG's technical approach to developing site-specific exposure zone(s) other than the Region suggesting that the sampling program would take possibly 3 years and might be too complicated to implement and interpret. The CPG requested and the Region agreed to provide a "high-level" response outlining its concerns within 2 weeks. On October 16, the CPG sent a letter summarizing its continued concerns and justifiable frustration with the Region's

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unwillingness to conduct a meaningful and timely engagement with the CPG on this matter. The Region provided its promised high-level response on October 23 and responded to the CPG's October 16 letter as well.

In its October 23 letter, Region 2 provided response to the CPG's proposed EZ sampling program. There are two main elements to the comments from Region 2 that require response: (1) need to conduct a multi-season survey, and (2) the necessity of incorporating a sediment chemistry investigation into the sampling program. The following responses are provided:

- Multi-Seasonal Survey - Region 2 states that any sampling program should be multi-seasonal, with sampling conducted, at a minimum, in the spring and fall but with full seasonal coverage preferred. The justification provided by Region 2 is that there is "*a high degree of variability associated with these data*" so multiple sampling events is required. Region 2 stated the need for multiple sampling efforts to reduce, or at least determine, the bounds on this variability. The CPG is unclear as to what variability Region 2 is referring given that the LPRSA observations and data collected to date suggest a static benthic community that is seasonally unaffected. Specifically, seasonal benthic community data collected throughout the 17-mile LPRSA under Region oversight as part of the RI shows station-specific changes in abundance that are well within expected seasonal changes. More importantly, minimal changes in station-specific species composition have occurred throughout the season within the LPRSA, indicating the existence of stable benthic communities throughout the year. Given the existing significant data on the seasonal composition, the CPG considers a single survey sufficient to describe the vertical depth of members of the benthic community.

Region 2 stated that it may require a multi-tidal sampling program. While very minor changes in vertical depth might occur with some benthic organisms that reside in intertidal sediment, the potential movements are at most millimeters and certainly not enough of a scale to justify a sampling program across tidal cycles, which would unnecessarily complicate the program and extend the schedule. The CPG requests any data or publications that Region 2 has relied on that support the need for a multi-tidal sampling program (i.e. indication of significant, tidally-induced movement of benthic organisms relevant to the data quality objective (DQO) of the proposed work).

Finally, Region 2 lists a number of seasonal differences including spawning, storage of food reserves, release of larvae, and larval and juvenile settlement, which are common characteristics of benthic communities but are not relevant to the DQO of the proposed work. The Region is requested to provide the literature citations that it has relied on to make this determination.

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- Sediment Chemistry Data - Region 2 identifies three DQOs for sediment chemistry data, including the need to develop correlations between benthic tissue concentrations and sediment, need to know the chemistry of feeding voids, and data for use in the bioaccumulation, and fate and transport models. Of the three DQOs identified by Region 2, the third DQO (collection of sediment data for use in the bioaccumulation, and fate and transport models) is the only one relevant in reducing uncertainty in applying the exposure zone CSM.

The first DQO, developing correlations between tissue concentrations with specific sediment chemistry is not necessary, nor a practical requirement. Determining a biota sediment accumulation factor (BSAF) is more relevant, but the BSAF is based on a simple ratio between tissue concentrations and sediment concentrations, not on correlations. More importantly collecting sediment chemistry along with tissue samples is not possible given the methods needed to collect sufficient tissue sample for chemical analysis. With respect to the Region's second DQO, the CPG does not see the value in determining concentrations in sediment surrounding feeding voids. Feeding voids were rarely observed in Germano's 2005 LPRSA Sediment Profile Imaging Survey. Moreover, the CPG is unaware of a methodology to identify feeding voids in a sediment grab sample; the CPG invites the Region to elaborate on how this could be conducted.

As presented in CPG's proposal, benthic tissue samples will be obtained by collecting composited tissue from numerous grab samples. In fact, the CPG sampling plan estimates that at least 160 grab samples will be needed to collect sufficient tissue sample to conduct 12 chemical analyses. Collecting sediment from each of the 160 grabs and expecting to develop meaningful correlations is not practical. Rather, given the large number of grab samples from which benthic organisms will be composited for the 12 tissue analytical samples, the CPG considers the resulting tissue chemical data to represent the site average. While collecting a focused number of sediment samples for use with the bioaccumulation, and fate and transport models, could reduce uncertainty in applying the exposure zone CSM, such samples would be better collected when determining the vertical position of benthic community members, not during tissue collection.

The CPG believes that site-specific exposure zone(s) could be resolved if the Region was willing to engage in a series of meaningful and substantive face-to-face meetings with experts from Region 2, EPA Headquarters and the CPG. How this matter is resolved is almost entirely up to the Region – the CPG would prefer an informal engagement with two teams of experts resolving the matter of an appropriate exposure zone(s).

The CPG requests that Region 2 include this letter into the Administrative Records for the 17-mile LPRSA operable unit of the Diamond Alkali Superfund Site and the Region's 8-mile FFS and Proposed Plan.

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Please contact Bill Potter or me with any questions or comments.

Very truly yours,
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DISPUTE STATEMENT ON EXPOSURE DEPTH (ZONE) ISSUES LOWER PASSAIC RIVER STUDY AREA 17-MILE REMEDIAL INVESTIGATION/ FEASIBILITY STUDY

Prepared for

Lower Passaic River Cooperating Parties Group

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November 2015

Introduction and Background

These documents have been prepared to support the formal Dispute Resolution process, as it relates to comments and assertions made by USEPA Region 2 (Region 2) on the findings of the Cooperating Parties Group (CPG) regarding the exposure depth or zone (hereafter exposure zone or EZ) issue for the 17-mile Lower Passaic River Study Area (LPRSA). The issue of what is an appropriate exposure zone has been discussed at two meetings between the Region and the CPG in February 2014 and February 2015. Following the February 2014 meeting, the CPG provided additional information on the matter at the request of Region 2 in a letter and attachments dated February 19, 2014. The Region did not provide a response to that letter and did not engage in further discussions with the CPG on this matter for a year - until February 2015. Nearly four months after the February 2015 meeting, Region 2 provided on June 1, 2015 its comments and assertions on the matter of a LPRSA exposure zone. Additional correspondence on this matter was received by the CPG by way of the Region's letters dated June 25, 2015 and July 9, 2015. As a result of the Region's June 1, 2015 letter, the CPG invoked dispute resolution pursuant to paragraph 64 of the May 2007 Administrative Order on Consent on June 12, 2015; this letter was acknowledged by the Region on June 25, 2015. The CPG sent a third letter on July 2, 2015 requesting the information that the Region had used to make its determinations; the Region responded to this request on July 9, 2015. The CPG provided draft Quality Assurance Project Plan (QAPP) worksheets for a proposed sampling program on September 17, 2015 to support the development of site-specific exposure zone(s).

Source of Disagreement/Dispute Between Region 2 and the CPG

There are two areas of disagreement between Region 2 and the CPG:

1. The depth at which the majority of benthic invertebrates feed and reside in the sediment bed of the LPRSA, and
2. Reliability and certainty of sediment chemistry concentration predictions for depth interval of less than 15 centimeters (cm), or approximately 6 inches.

Each of these issues will be separately discussed in this document, and for clarity and ease of review, the CPG's position on both areas of disagreement are presented in accompanying papers by Windward Environmental and Anchor QEA, respectively.

Site-Specific Exposure Zone At Which the Majority of Benthic Invertebrates Feed and Reside Is Supported by Site-Specific Data, USEPA Guidance and Previous Documents Prepared by the Region.

Much of the disagreement between the CPG and Region 2 regarding the depth at which benthic invertebrates reside and feed is a difference on the identification and use of an appropriate and site-specific exposure zone for those benthic invertebrates that serve as a food source for benthic-feeding fish, and how this depth relates to the structure of the biologically active zone (BAZ). First, it is important to clarify the CPG's position as follows:

- The EZ represents the zone in which the majority of benthic invertebrates that serve as a food source for fish reside, while the BAZ refers to the maximum depth to which the biological activity of benthic invertebrates occurs. The EZ can be viewed as a subdivision of the BAZ that is found near the sediment surface for these benthic invertebrates that serve as a food source. Because of the need for an oxygenated environment, most of the benthic invertebrates in the LPRSA are concentrated above the Redox Potential Discontinuity (RPD) that denotes the depth to which oxygen is present in the sediments. This is well-established and supported in the scientific literature such as Rosenberg (1978) where it was *“found that a high proportion of the animals were restricted to the upper 5 cm of the sediments in the Byfjord most probably as a result of the RPD-layer being close to the surface.”*¹
- In its June 1, 2015, letter, Region 2 states that it does not support a benthic community EZ *“as shallow as 2 cm”*. Interestingly, and contrary to their June 2015 and subsequent statements, Region 2 stated in a May 1993 draft scope of work² for the Diamond Alkali OU2 that *“the upper 2 centimeters of sediment correspond to the biological active zone and thus provide a good representation of exposure of biota to contamination”*. The CPG is not aware of any significant change in the scientific literature of the last 20 years that would change the Region's 1993 position of an EZ of 2 cm for the LPRSA.
- In its July 9, 2015 letter, Region 2 states that it does not believe that the depth of the RPD correlates with the limit of the BAZ. The CPG agrees that the RPD does not represent the limits of the BAZ, but it does provide a vertical barrier to smaller benthic invertebrates burrowing deeper that are a primary food source to bottom feeding fish.
- It is important to note that the CPG has never claimed that all members of the benthic community are exposed to only the upper 2 cm of sediment. However, the important element of the EZ Conceptual Site Model (CSM) is that those members of the LPRSA benthic community that constitute the majority of the food resource for benthic-feeding fish reside near the surface, in aerobic sediment (i.e., upper 2 cm). The CPG does not claim that all biological activity in the LPRSA is restricted to the EZ, such that the BAZ equals the EZ. Rather, based on site-specific data, the CPG clearly has identified very limited instances where biological activity is found below the interval (i.e., greater than 2 cm) where most LPR benthic invertebrates reside and feed.

¹ Quoted from Pearson and Rosenberg (1978).

² Scope of Work to Investigate and Assess Contamination in the Passaic River and Estuary which constitutes the Second Operable Unit of the Diamond Alkali Superfund Site. Page 3. Dated May 9, 1993

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- The CPG agrees with statements made in EPA's 2009 guidance³, which states that *"it is important that the sediment samples collected be representative of the sediments where the species normally forages and not a homogenized sediment core representing the entire bed of contaminated sediment"*. It goes on to state that *"for most organisms, the surficial sediments are most reflective of the organism's immediate exposure/foraging history, and generally, smaller depths of the surficial layer, e.g., 0 to 2 cm, are preferred over larger depths, e.g., 0 to 30 cm"*. It further states that *"for deeper burrowing organisms such as some clams and polychaetes, slightly larger surficial depths, e.g., 0 to 5 cm, might be more appropriate of their recent exposure history"*. Thus, for the purposes of estimating future exposure concentrations for benthic invertebrates and bottom-feeding fish, it would seem more logical to rely on the sediment concentrations predicted for discrete depth intervals (e.g. 0-2 cm or 0-5 cm) rather than a homogenized average from 0-15 cm as Region 2 supports which is greater than and not representative of the actual exposure zone for most benthic invertebrates.

The use of a site-specific exposure zone of 2 cm is clearly supported by the LPRSA data and the scientific literature as well EPA's guidance and past documents prepared by Region 2. Section 1 of this document establishes lines of evidence that form the specific bases for a 2 cm exposure zone and are summarized as follows:

- The depth of the RPD is approximately 2 cm for the Lower Passaic River. The RPD provides a primary vertical barrier to deeper burrowing by small benthic invertebrates that serve as the primary food source to bottom feeding fish.
- Benthic invertebrates in the Lower Passaic River are dominated by species that live near the sediment surface.
- Benthic invertebrates in the LPRSA are dominated by detritivores that feed on material at the sediment surface.
- There is a lack of evidence of significant biological activity below the RPD (i.e., 2 cm) in the LPRSA.
- The biological community structure in the LPRSA is similar throughout the year.

Region 2 Is Incorrect In Its Assertions Regarding the Reliability And Certainty of Sediment Chemistry Concentration Predictions For A Depth Interval of Less Than 15 cm

In the June 1, 2015 letter, Region 2 stated that the average contaminant concentration over the top 15 cm of sediment should be used in the bioaccumulation model for the 17-mile LPRSA. This position is based, in part, on Region 2's contention that concentrations in an EZ as shallow as the top 2 cm cannot be reliably calculated by the CPG contaminant fate and transport (CFT) model. This contention derives from incorrect assertions made by Region 2 in its June 1, 2015 letter and in the subsequent letters dated June 25, 2015 and July 9, 2015. Region 2's conclusion

³ Estimation of Biota Sediment Accumulation Factor (BSAF) from Paired Observations of Chemical Concentrations in Biota and Sediment (EPA/600/R-06/047 ERASC-013F February 2009)

is completely unsupported and contrary to the results of their own 2014 FFS CFT model which computes concentrations for 0 to 2 cm layers that are different than deeper layers such as 10-15 cm. The CPG believes and is confident that its sediment transport (ST) model which is derived from the same model used by the Region in its 2014 Focused Feasibility Study (FFS) can reliably predict bed elevation changes at scales as small as 2 cm. Additionally, this is supported by the ability of the CPG's version of the models to accurately predict water column contaminant concentrations (i.e., matching the levels measured in the Chemical Water Column Monitoring [CWCM] program), and provides confidence in the CFT model's concentrations in the 0 to 2 cm layer.

Region 2 also contends that the CFT model's average concentration over the top 15 cm is a reasonable surrogate for the average concentration in the top 2 cm. It does so without evidence and in direct contradiction to its own 2014 FFS model. The CPG disagrees with this contention, and will demonstrate that this is not supported by site-specific data.

Section 2 of this document, prepared by Anchor QEA, LLC, demonstrates why Region 2's assertions are incorrect and the Region's direction to use the 15 cm average to represent the 2 cm average is indefensible and contrary to their own modeling results.

The CPG's position and conclusions on the use of a 2 cm exposure zone are technically correct and are supported by the CPG's 17-mile LPRSA model and to a lesser extent the Region's 2014 FFS model:

- The modeling framework employed in both CPG and Region's versions of the models operate with processes occurring on a scale of a cm or less, because they actually occur in the river on that scale. Thus, the sediment transport (ST) and chemical fate and transport (CFT) models can reliably calculate concentrations in sediment at the scale of 0 to 2 cm because fate and transport processes occur on this scale.
- The 17-mile CWCM empirical data constrain and validate the models predictions of 0 to 2 cm sediment concentrations.
- Contrary to the Region's assertion, the CFT model's 0 to 15 cm average concentrations are poor surrogates for the 0 to 2 cm concentrations. A comparison of paired top 2 cm and top 15 cm sediment concentrations for chemicals of potential concern support the 2 cm predictions.

Summary

The Region has failed to provide any substantive and cogent basis for denying the use of an exposure zone as shallow as 2 cm. The Region's arguments have continued, throughout the nearly 2 years of this issue to be either (1) vague and generalized and rely largely on invoking an

undefinable uncertainty, (2) providing partial or incorrect information to support its position, or (3) more recently saying data collection would take too long or be too complicated. This has been true since the dispute began with the Region's June 1, 2015 letter and continues with its recent letter on October 23, 2015. Additional hurdles have been presented with Region 2's positions:

- The Region's May 2014 expert paper prepared by a contractor to CDM-Smith was incomplete and severely flawed because it cited maximum burrowing depths and ignored data that the vast majority of benthic invertebrates reside within a few centimeters of the surface.
- The Region is either ignoring or contradicting the results of its own 2014 FFS model when it states that the model cannot reliably predict concentrations for intervals of less than 15 cm.
- The Region has inexplicably changed its position on a 2 cm exposure zone as evidenced by its May 1993 OU 2 Scope of Work.
- The Region has been reluctant if not unwilling to meet with the CPG and have meaningful exchange on this matter – it has avoided meeting on this issue with the CPG since February 2015.

In response to the Region's invitation in its June 1, 2015 letter, the CPG has prepared a draft QAPP and provided key worksheets to the Region to support the collection of data to develop a site-specific exposure zone. In short, Region 2's responses have prevented the CPG from finalizing and utilizing a site-specific and truly representative exposure zone for the 17-mile RI/FS. The CPG believes that the confrontational approach of dispute resolution on site-specific exposure zone(s) could be avoided and the matter resolved if the Region is willing to engage in a series of meaningful and substantive face-to-face meetings with experts from Region 2, EPA Headquarters and the CPG.

DISPUTE STATEMENT ON EXPOSURE DEPTH ISSUES PERTAINING TO EXPOSURE DEPTH (ZONE) CONCEPTUAL SITE MODEL

17-MILE LOWER PASSAIC RIVER STUDY AREA REMEDIAL INVESTIGATION/ FEASIBILITY STUDY

Prepared for

Cooperating Parties Group

November 6, 2015

Prepared by:



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Acronyms

BAZ	biologically active zone
CPG	Cooperating Parties Group
CSM	conceptual site model
EZ	exposure zone
FWM	food web model
LOE	line of evidence
LPR	Lower Passaic River
LPRSA	Lower Passaic River Study Area
PCA	principal components analysis
Region 2	US Environmental Protection Agency Region 2
RM	river mile
RPD	redox potential discontinuity
SDI	Swartz's Dominance Index
SPI	sediment profile imaging

1 Source of Disagreement/Dispute Between USEPA Region 2 and CPG

There are two areas of disagreement between the US Environmental Protection Agency Region 2 (Region 2) and the Cooperating Parties Group (CPG):

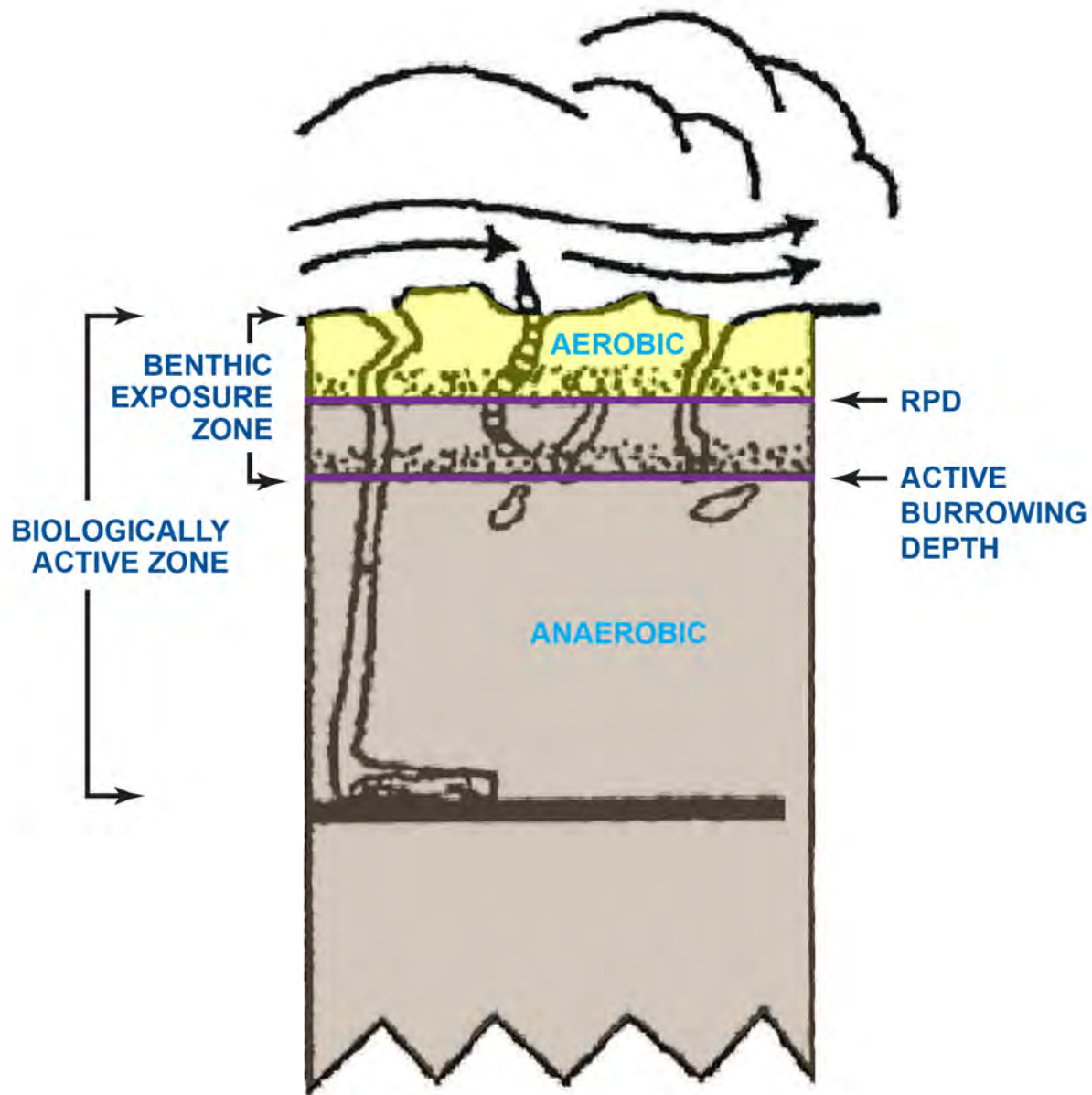
1. The depth at which the majority of benthic invertebrates feed and reside in the sediment bed of the Lower Passaic River (LPR)
2. Reliability and certainty of sediment chemistry concentration predictions for the depth interval of less than 15 cm (6 in.); this area of disagreement is discussed by Anchor QEA in Volume 2 of this document

Much of the disagreement between CPG and Region 2 regarding the depth at which benthic invertebrates reside and feed is the result of a) a difference in the identification and use of an appropriate and site-specific exposure zone (EZ) for those benthic invertebrates that serve as a food source for benthic-feeding fish, and b) how this depth relates to the structure of the biologically active zone (BAZ).

1. The EZ represents the zone in which the majority of benthic invertebrates that serve as a food source for fish reside, while the BAZ refers to the maximum depth to which the biological activity of benthic invertebrates occurs. For the benthic invertebrates that serve as a food source, the EZ can be viewed as a subdivision of the BAZ that is found near the sediment surface (Figure 1). Because of the need for an oxygenated environment, most of the LPR benthic invertebrates are concentrated above the redox potential discontinuity (RPD) boundary, which is typical in such an environment. This fact is well established and supported in the scientific literature, such as Rosenberg (1977), wherein it was “found that a high proportion of the animals were restricted to the upper 5 cm of the sediments in the Byfjord most probably as a result of the RPD-layer being close to the surface” (Pearson and Rosenberg 1978).
2. In its June 1, 2015, letter to CPG, Region 2 stated that it does not support a benthic community EZ as shallow as 2 cm (Vaughn 2015a). Interestingly, and contrary to its June 2015 statements, Region 2’s May 1993 draft scope of work for Diamond Alkali Operable Unit 2 stated that “the upper 2 cm of sediment correspond to the biological active zone and thus provide a good representation of exposure of biota to contamination” (USEPA 1993).
3. In its July 9, 2015, letter to CPG, Region 2 states that it does not believe that the depth of the RPD layer correlates to the limit of the BAZ (Vaughn 2015b). CPG agrees that the RPD layer does not represent the limits of the BAZ, but it does provide a vertical barrier that prevents smaller benthic invertebrates, a primary food source for bottom-feeding fish, from burrowing deeper than the RPD layer.

4. Moreover, CPG has never claimed that **all** members of the benthic community are exposed to only the upper 2 cm of sediment. However, the important element of the EZ conceptual site model (CSM) is that those members of the Lower Passaic River Study Area (LPRSA) benthic community that constitute the **majority** of the food resources for benthic-feeding fish reside near the surface, in aerobic sediment (i.e., upper 2 cm). CPG does not claim that **all** biological activity in the LPRSA is restricted to the EZ, such that the BAZ equals the EZ. Rather, based on site-specific data, CPG clearly has identified limited instances where biological activity is found below the interval (i.e., deeper than 2 cm) where most LPRSA benthic invertebrates reside and feed.

The following sections present the analyses and lines of evidence (LOEs) that form the basis for CPG's conclusions concerning the portion of the benthic community that serves as the primary source of food for benthic-feeding fish.



Source: Figure revised from Swift et al. (1996); color and labels have been added.

Figure 1. CSM of the LPR EZ

2 Background

The fundamental question addressed herein is “At what depth in the sediment of the LPR do the majority of benthic invertebrates, which serve as a food source for benthic-feeding fish, reside?” Fish species that rely on benthic invertebrates (i.e., invertivores) and/or living and dead organic matter (i.e., benthic omnivores) as a food source typically feed at the sediment surface, or by sifting through material in the upper few centimeters of the sediment surface.

When sediments are contaminated, knowing the depth at which the majority of the benthic invertebrates live is important, since this food source serves as a trophic mechanism to transfer contaminants associated with sediment to higher trophic organisms. Based on an evaluation of multiple LOEs that rely on LPRSA site-specific data and a review of published literature for other water bodies, the CPG has concluded that the EZ for benthic invertebrates that serve as the primary food source for benthic-feeding fish is in the upper several centimeters of the sediment surface. Becker and Chew (1987), for example, investigated flatfish foraging behavior over the diurnal cycle in an urban environment. The fish they studied were opportunistic feeders that predominantly fed on what was most abundant in the upper few centimeters of sediment, the common polychaetes *Capitella* spp. Rhoads et al. (1978) concluded that since productivity in early successional stages generally exceeds that of later stages, benthic assemblages dominated by pioneering species represent an enhanced food resource for demersal fishes. Based on fish community and tissue collection surveys in the LPRSA (Windward 2011, 2010), it is clear that the majority of fish in the LPRSA are benthic feeders and opportunistic omnivores. Therefore, it is highly probable that LPR benthic-feeding fish feed selectively on shallow-dwelling and abundant infaunal invertebrates.

2.1 EXPOSURE ZONE CONCEPTUAL MODEL

The CSM of the LPR EZ is presented in Figure 1. The vertical profile of sediment in the LPR consists of multiple physiochemical and biotic zones. Because oxygen is a fundamental factor in organism survival, the principal physiochemical zone is based on the presence of oxygen. Oxygenated sediments are found at the sediment surface, while deeper sediments lack oxygen. The depth at which sediment is found to be oxygenated depends on a number of factors, including the availability of oxygen in the overlying water, the relative biological oxygen demand of the sediment, and the degree to which the sediment is actively reworked by benthic invertebrates. The demarcation between the oxygenated aerobic zone and the anaerobic zone, where oxygen is lacking, is termed the RPD layer. When viewed in profile, sediments that contain oxygen are often light tan in color due to the presence of particles coated with ferric hydroxide, while reducing sediments that lack oxygen appear darker (Germano & Associates 2005).

Since benthic invertebrates only can survive in conditions where oxygen is present, the majority of benthic invertebrates live within the aerobic zone, where oxygen is prevalent. In Figure 1, this means that they live in the near-surface sediment above the RPD. Some benthic invertebrates have adapted to be able to exploit anoxic sediment, and thus can be found below the RPD. However, any organisms located below the RPD always maintain contact with the oxygenated surface sediment or overlying water. Examples of such organisms include deep-burrowing clams, which can be found at depth, but the siphons of which are found at the sediment-water interface for feeding and respiration; certain species of polychaetes and oligochaetes, which form vertical tubes to the surface that are irrigated with overlying water; and polychaetes, which build burrow galleries that are also irrigated with overlying, oxygenated water.

The following sections present the LOEs that form the basis for CPG's conclusions concerning the location of the benthic community that serves as the primary source of food for benthic-feeding fish. LOEs that support CPG's conclusions, include:

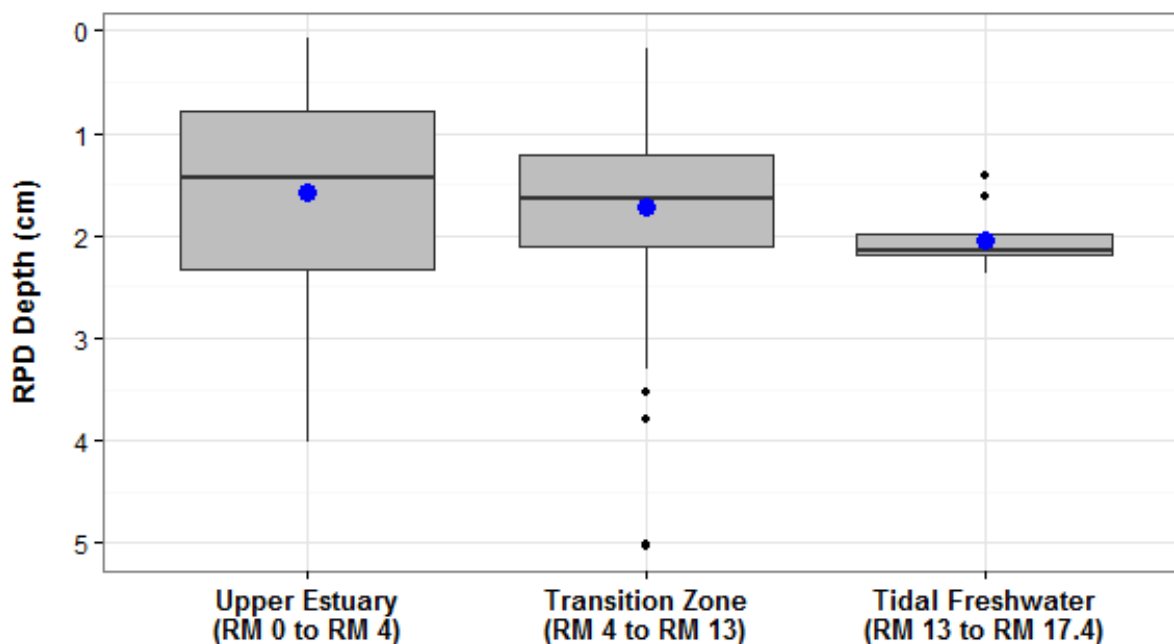
- ◆ The depth of the RPD boundary is approximately 2 cm for the LPR.
- ◆ Benthic invertebrate abundance in the LPRSA is dominated by species that live near the sediment surface.
- ◆ Benthic invertebrate biomass in the LPRSA is dominated by detritivores that feed on material at the sediment surface.
- ◆ There is a lack of evidence of significant biological activity below the RPD in the LPRSA.
- ◆ The biological community structure in the LPRSA is similar throughout the year.

3 Analysis and Conclusions

3.1 THE DEPTH OF THE RPD IS APPROXIMATELY 2 CM FOR THE LPRSA

The RPD was measured using sediment profile imaging (SPI) surveys conducted by Germano & Associates (2005) over a five-day period in June 2005. This method evaluates the contrast in optical reflectance between the aerobic and anaerobic layers of sediment. Shallow, overlying aerobic sediments appear olive or tan in color because of the ferric hydroxide, whereas deeper, underlying anoxic sediments appear grey or black in color. The distinguishable boundary between the two layers is defined as the RPD.

Germano & Associates (2005) took 2 image replicates at 5 stations along each of the 27 cross-river transects, yielding a total of 268 images from 134 stations (only 4 stations at Transect 27 could be surveyed). Using Germano & Associates (2005) data, the mean RPD depths for the LPRSA were 1.6 cm for the upper estuary (LPRSA river mile [RM] 0 to RM 4), 1.7 cm for the transition zone (RM 4 to RM 13), and 2.1 cm for the tidal freshwater zone (RM 13 to RM 17.4) (Figure 2). For the purposes of developing the benthic-to-fish trophic transfer component of the LPRSA food web model (FWM), the CPG rounded the RPD to 2 cm.



Source: data reported by Germano & Associates (2005)

Note: Blue points indicate the mean RPD depths within each of the three zones.

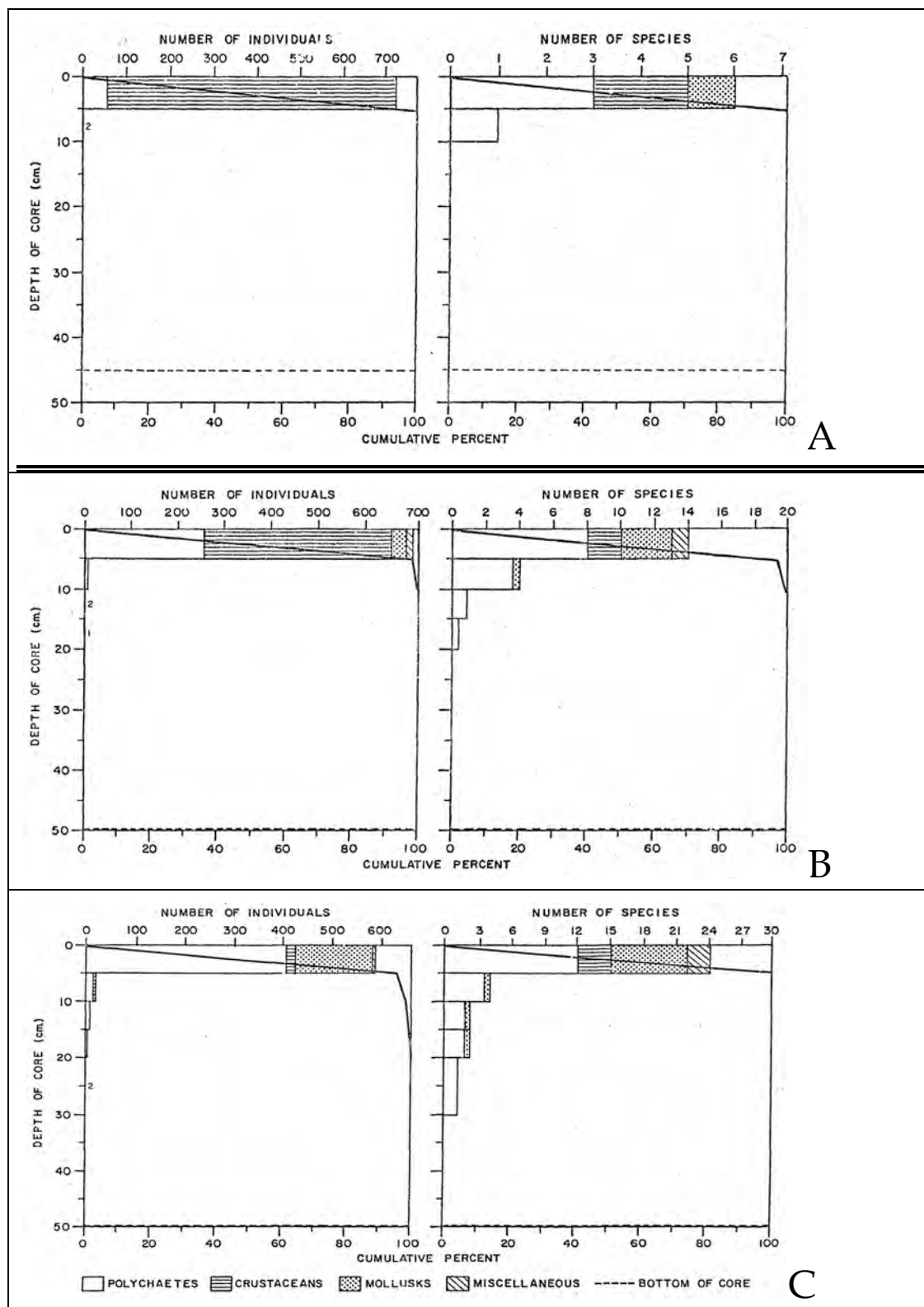
Figure 2. Distributions of RPD depths across the three zones within the LPR

3.2 BENTHIC INVERTEBRATE ABUNDANCE IN THE LPRSA IS DOMINATED BY SPECIES THAT LIVE NEAR THE SEDIMENT SURFACE

Based on the results of the SPI survey data, Germano & Associates (2005) concluded that benthic invertebrate communities in the LPRSA are generally in a state of early or transitional community succession. Even in locations where species associated with mature communities (i.e., head-down deposit feeders) are found, the community is most often dominated by a small number of species (e.g., the oligochaete *Limnodrilus hoffmeisteri*) (Windward 2014a) that often live near the sediment surface. Some stations farther upstream (i.e., in the tidal freshwater zone) are inhabited by more stable, mature, and diverse communities of invertebrates (Germano & Associates 2005; Windward 2014a). Data from the fall 2009 and spring and summer 2010 community surveys (Windward 2014a, b) noted the presence of many species that in the literature, are associated with early successional stages (e.g., small-bodied, relatively mobile opportunists that feed near the sediment surface on detrital material) (Pearson and Rosenberg 1978; Rhoads and Germano 1986; McCall and Soster 1990; Soster and McCall 1990; Germano & Associates 2005).

Communities in early and transitional stages of succession are characteristically inhabited by species of invertebrates that live near the sediment surface and feed on very shallow surface sediment and detrital matter (i.e., detritivore feeding guild), rather than feed and/or live deeper in sediment, consuming bedded sediment (i.e., deposit feeder guild) (Pearson and Rosenberg 1978; Rhoads and Germano 1986; McCall and Soster 1990; Soster and McCall 1990). Early and transitional stages were observed visually in June 2005 using SPI (Germano & Associates 2005) and are fairly abundant members of the LPRSA benthic community, particularly in the upper estuary zone (RM 0 to RM 4) (Windward 2014a, b).

As a whole, benthic communities in upper estuary and transition zone waters are exposed primarily in shallow sediment, where the majority of benthic biomass is most often found (Mermillod-Blondin et al. 2001; Kirchner 1975; Nilsen et al. 1982). Figure 3 provides a visualization of the typical distribution of biomass over depth. It is expected that the biomass in shallow sediment (rather than the relatively sparse, deeply buried biomass) accounts for the vast majority of what is transferred up the food chain to fish (PWS RCAC 2004). For example, fish and crabs generally do not consume whole, buried bivalves, but rather “nip” or “crop” the siphon tubes of those bivalves that are available near the sediment surface (Kvitek and Beitler 1991; Kanakaraju et al. 2008). Deep burrowing is often a strategy to avoid predation (Flynn and Smee 2010); as a result, such burrowing is expected to reduce the level of trophic transfer of contamination from bedded sediment to higher trophic levels via benthic invertebrate tissues. Additionally, deep burrowing organisms, such as bivalves, feed at the surface and from the overlying water column. Consequently, the concentrations to which these organisms are exposed are likely to be more consistent with concentrations in surface sediment than with those in sediment below the RPD.



Source: Figure format revised from Nilsen et al. (1982).

Note: Panels A and B show results from two sampling locations in muddy bottoms; panel C shows result from a mixed sand and mud location.

Figure 3. Vertical distribution of abundance and taxa in soft sediments

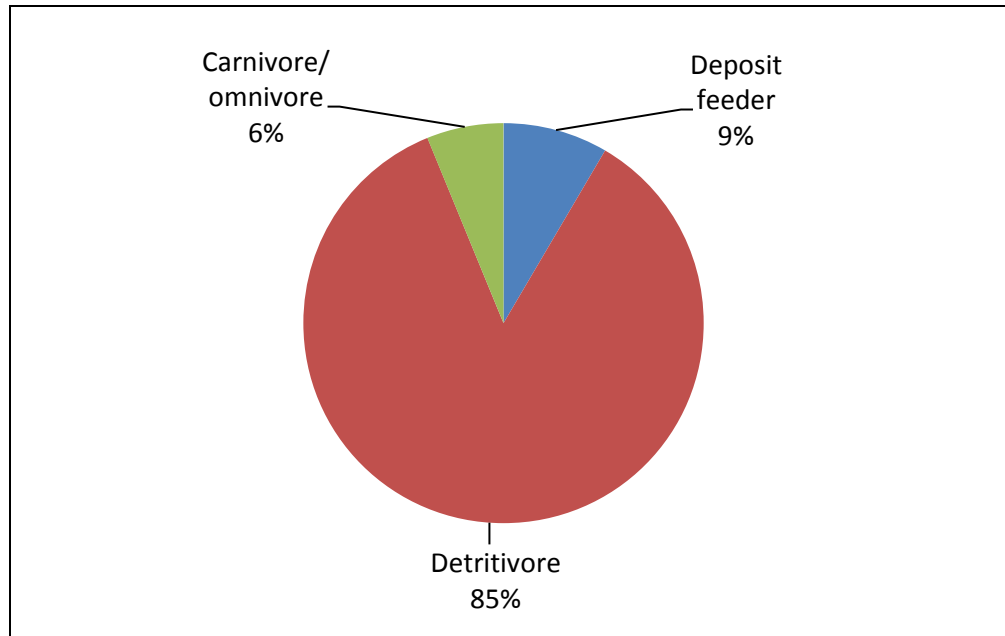
3.3 BENTHIC INVERTEBRATE BIOMASS IN THE LPRSA IS DOMINATED BY DETRITIVORES THAT FEED ON MATERIAL AT THE SEDIMENT SURFACE

CPG conducted a detailed investigation of the feeding strategies of each observed taxonomic group from the fall 2009 and spring and summer 2010 surveys (Windward 2014a, b). The strategies were reported or inferred from available literature and databases (e.g., Fauchald and Jumars 1979; Vieira et al. 2006; Macdonald et al. 2010; USEPA 2012). The majority of species in the LPRSA were found to most likely consume some type of detrital material, including leaf litter, fluff (or flocculated, unconsolidated surface sediment), or suspended particulates (e.g., algae, disturbed fluff, sewage, or other solid runoff).

As noted, there is a fairly shallow RPD layer in the LPRSA (2 cm or less on average), and the community structure and successional stages in the LPRSA indicate that most species are opportunistic feeders and feed and live in shallow sediment (rather than feeding on deep, bedded sediments) (Germano & Associates 2005; Pearson and Rosenberg 1978). These LOEs support the claim that benthic invertebrates in the LPRSA are dominated by species that feed on surface material.

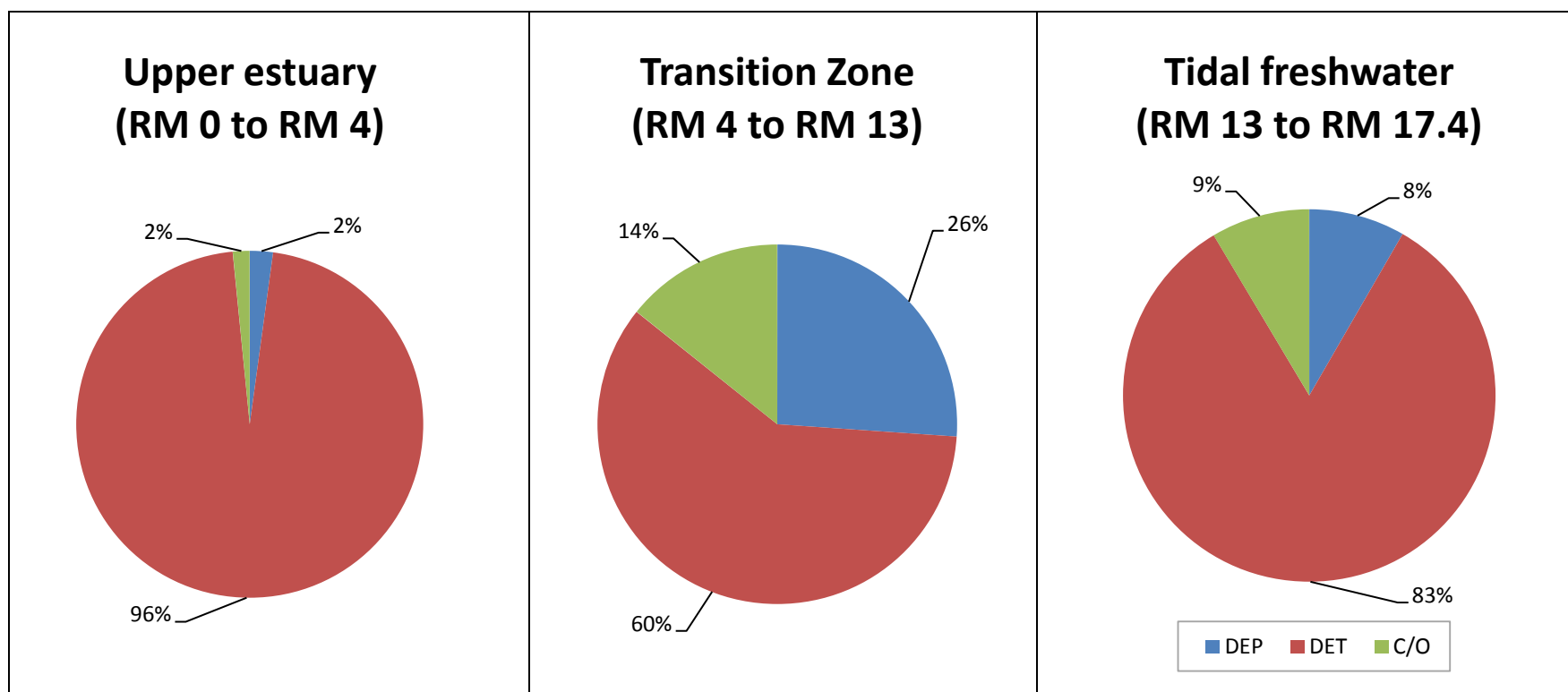
In order to better understand the structure of the benthic community and to meet the information needs of the FWM, the CPG estimated the biomass of all species found in each of the three salinity zones. Biomass of invertebrates was estimated using biomass values from the literature (i.e., mass-per-individual) (CBBMP 2014; Whiles and Goldowitz 2005; Barbone et al. 2007; Bloom et al. 1972; Douce 1976; Ricciardi and Bourget 1998; Smit et al. 1993; Sapkarev 1967; Newton 2013) and site-specific abundance data (fall 2009) (Windward 2014a). Based on the best available estimate, detritivores account for approximately 85% of all biomass across the LPRSA (Figure 4) and dominate biomass within each salinity zone. Detritivores account for a greater portion of the biomass in the upper estuary zone (96% of total biomass) and tidal freshwater zone (83%) than in the transition zone (60%) (Figure 5). Primary surface feeding species include small-sized bivalves (e.g., *Macoma balthica* and *Corbicula* sp.), which are suspension (filter) feeders and/or near-surface deposit feeders. Other examples of such species include small crustaceans (e.g., *Gammarus* spp.), many species of worms (e.g., *Marenzelleria viridis*), and larval insects (e.g., many species within family Chironomidae). Maximum burrowing depths presented by Prezant (2014) in his analysis as an expert for Region 2 are not the same as typical burrowing depths, which are generally much shallower (e.g., 4–6 cm for *M. balthica*) (Aller and Yingst 1985), especially for the small-sized individuals collected in the LPRSA. Representative samples of LPRSA benthic invertebrate individuals collected during the benthic community surveys of 2009 and 2010 and shown to Region 2 staff during the January 27, 2015, meeting were small relative to published size ranges. Within the same species, smaller individuals can be expected to burrow to shallower depths than larger individuals.

Based on the foregoing, CPG concluded that the vast majority of the sediment-dwelling organisms present in the LPRSA that serves as forage for upper-trophic level consumption is represented by shallow-burrowing, surface-feeding detritivores; as such, this majority supports the use of a shallow (i.e., 2-cm) EZ in the CPG FWM.



Note: Carnivore/omnivore category includes predators, predator/parasites, and omnivores, all of which will consume live tissue as available. Deposit feeders directly consume sediment. Detritivores consume a variety of materials, including coarse plant matter, fluff, and particulates.

Figure 4. Site-wide distribution of estimated LPRSA biomass (fall 2009) among generalized feeding types



DEP – deposit feeder

DET – detritivore

C/O – carnivore/omnivore

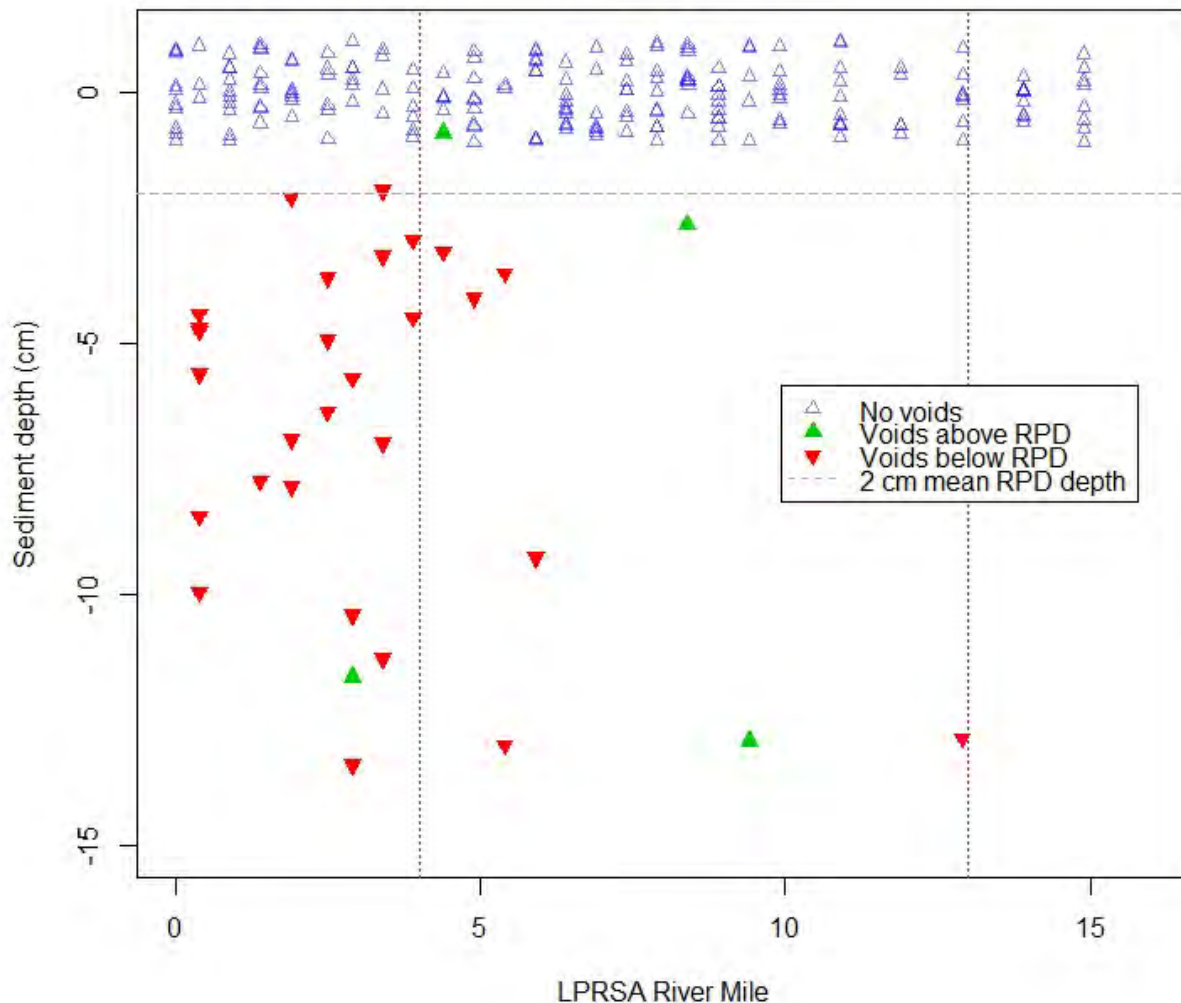
Note: Carnivore/omnivore category includes predators, predator/parasites, and omnivores, all of which will consume live tissue as available. Deposit feeders directly consume sediment. Detritivores consume a variety of materials, including coarse plant matter, fluff, and particulates.

Figure 5. Within-zone distributions of estimated LPRSA biomass (fall 2009) among generalized feeding types

The use of a shallow EZ for the FWM is not a novel approach. The models of contaminant transfer from sediments to benthic invertebrates for the Housatonic and Hudson Rivers both assumed mixing depths between 4 and 10 cm (Connolly 2015), shallower than the typical BAZs observed for these rivers, which generally ranged between 15 and 20 cm. These shallower mixing zones were assumed to be the source of most contamination entering the aquatic food web from the benthic zone.

3.4 THERE IS A LACK OF EVIDENCE OF SIGNIFICANT BIOLOGICAL ACTIVITY BELOW THE RPD IN THE LPRSA

The 2005 SPI survey (Germano & Associates 2005) provided an analysis of 269 images taken along transects along the lower 15 mi of the LPR. Bottom conditions above RM 15 contained too much sand or cobble to allow images to be obtained. For each of the 269 images, Germano & Associates (2005) noted the presence of feeding voids and the depths at which they were found. Consistent with the EZ CSM, the SPI photographs identified some biological activity below the RPD. Also consistent with the EZ CSM, the presence of biological activity, as evidenced by the presence of feeding voids, was rarely identified, only appearing in approximately 10% of the images (28 of 269). Region 2, in its response to the CPG's analysis of the LPRSA benthic community EZ, included a graphic plot showing the presence of feeding voids below the RPD that was based on the interpretation of the SPI images by Germano & Associates (2005). This graph is misleading, as it shows only the stations where a feeding void below the RPD was observed (which was only found in 10% of the images) and ignores the rest of the observations on feeding voids presented in the dataset. Figure 6 plots the depth of observed feeding voids for all 269 images. From Figure 6, it is obvious that biological activity, in the form of feeding voids below the RPD, is a relatively rare occurrence in the LPRSA. When all of the data are presented (stations where feeding voids were not detected are shown as jittered around 0 cm in Figure 6), the observations show a pattern of biological activity that is consistent with the EZ CSM. The CPG has not stated that the BAZ does not extend beyond the RPD, but rather that the evidence of such activity is rare in the empirical data available for the LPRSA. The abundant benthic invertebrates collected in the 2009 and 2010 surveys (Windward 2014a, b), the literature-based categorization of many of the species living and feeding near the sediment surface, and the small size of the benthic invertebrates all support the conclusion that the majority of the LPRSA benthic community resides within the EZ and above the RPD.



Source: Data reported by Germano & Associates (2005).

Note: Sampling locations where no voids were observed are jittered around 0 cm to show the number of locations at which there was no evidence of feeding in proportion to locations where voids were observed. The categorization of locations as above or below the RPD is based on the location-by-location RPD values. Vertical, dashed lines indicate breaks between salinity zones. The four locations with voids above the RPD layer tended to have fine, recently deposited sediment. Profile images from those locations showed a fully oxidized sediment profile or a faint or indistinguishable RPD boundary (Germano & Associates 2005).

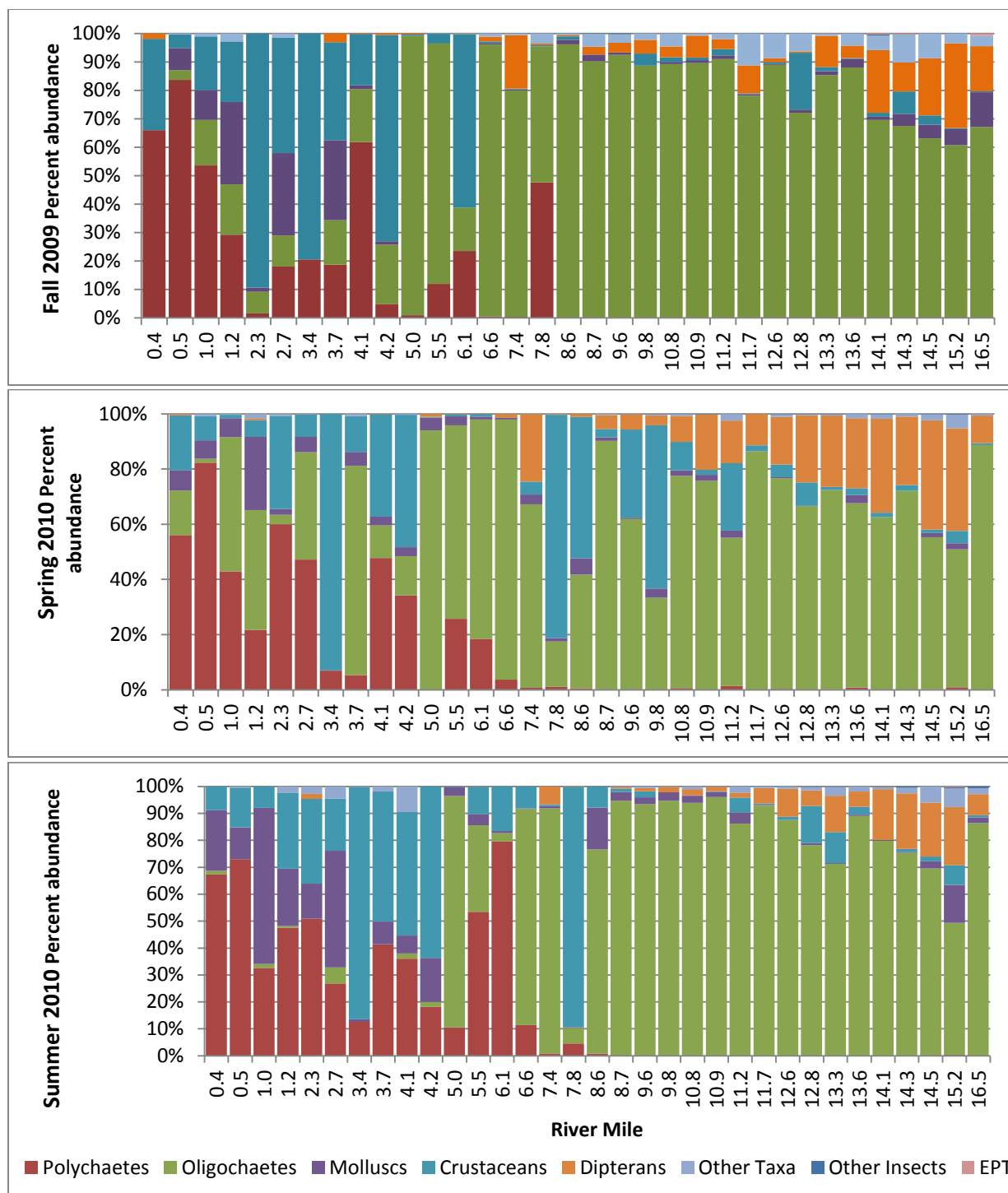
Figure 6. Maximum depth of active or relict feeding voids in SPI photographs

3.5 THE BIOLOGICAL COMMUNITY STRUCTURE IN THE LPRSA IS SIMILAR THROUGHOUT THE YEAR

Sediment for benthic invertebrate community analysis (i.e., taxonomy and structure) was collected at 33 sampling locations in the LPRSA over three seasons (i.e., fall 2009 and spring and summer 2010) (Windward 2014a, b). All stations were reoccupied in order to provide a measure of consistency among seasons. Based on these surveys, it appears that differences in benthic invertebrate community structure in the LPRSA remain fairly consistent throughout the year. Figure 7 presents the major taxonomic

groups at individual sampling locations (sorted from downstream to upstream) over three seasons, and the community structure looks fairly similar across all seasons.

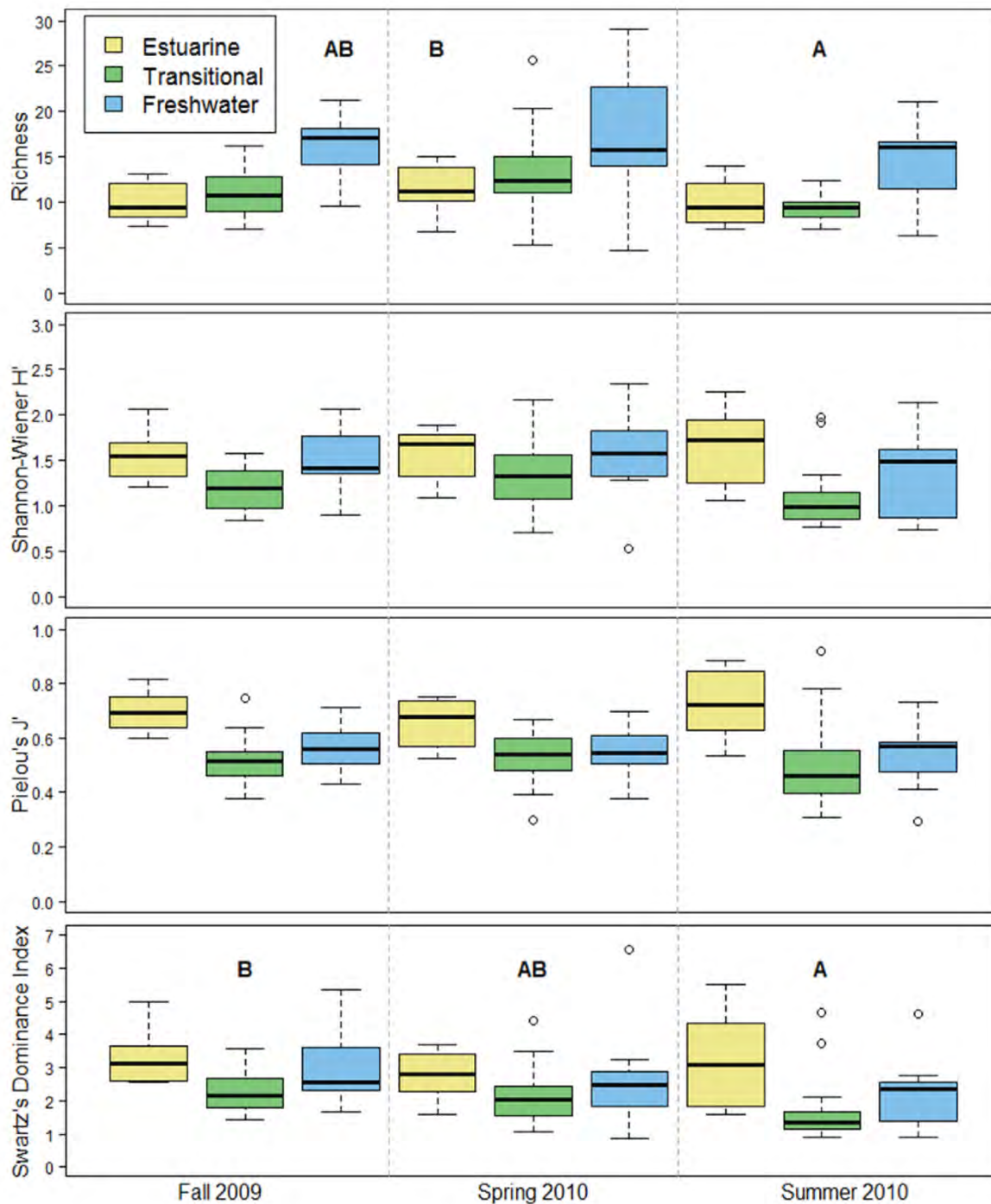
Slight changes in community structure are noticeable within salinity zones. For example, mollusks are more prevalent in the upper estuary zone during the summer, whereas oligochaetes are more prevalent in the spring. Similarly, polychaetes appear to shift further upstream in the summer and fall than in the spring. These changes are consistent with the known seasonal migration of the salt wedge in the LPRSA resulting from higher freshwater flows during the spring and lower flows in summer and fall. The tidal freshwater zone appears to change very little in composition across seasons.



EPT – Ephemeroptera, Plecoptera, Trichoptera

Note: Only re-sampled locations are shown. Chironomidae are included in Dipterans category; Other Insects category includes all non-Dipteran and non-EPT insects; Other Taxa category includes all other non-insect taxa, including Turbellaria, Nematoda, Nemertea, Hirudinea (leeches), and others.

Figure 7. Comparison of major benthic invertebrate taxonomic groups present in the LPRSA for the 2009 and 2010 surveys



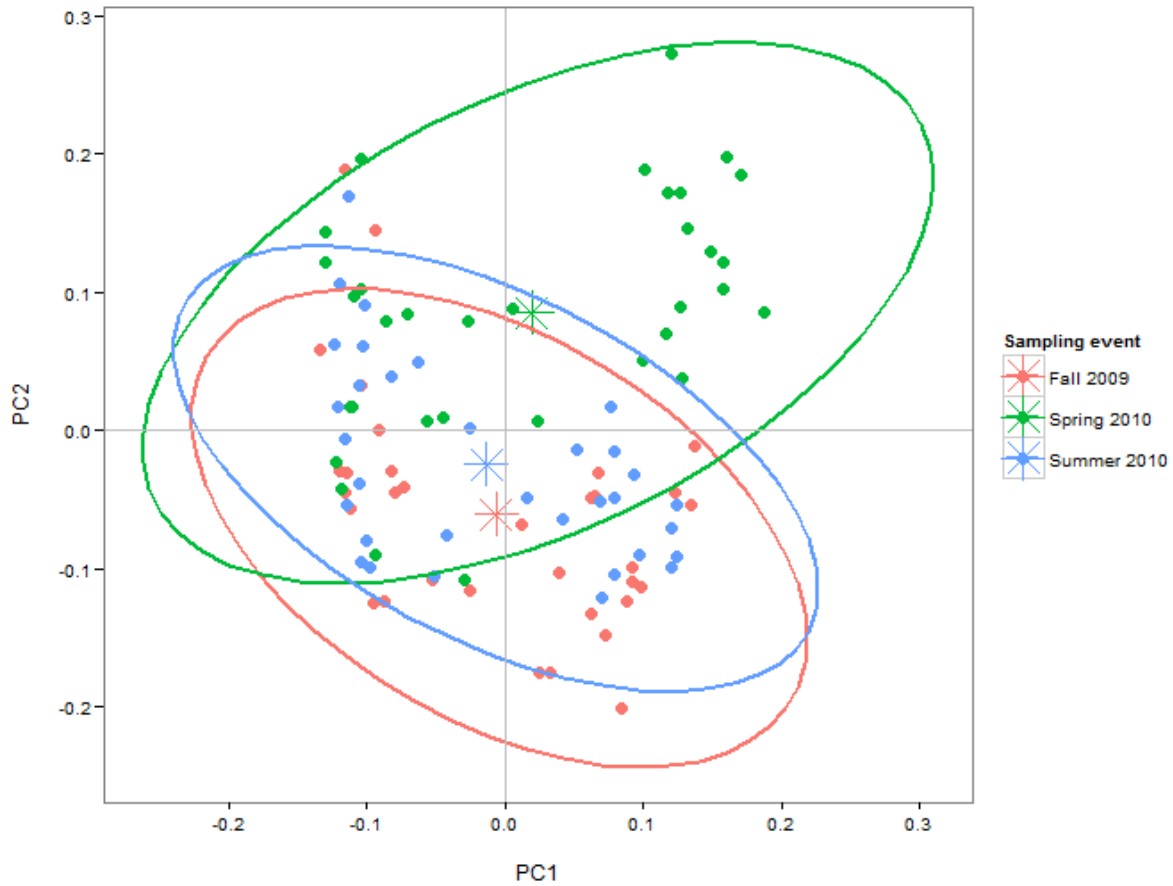
Note: Letters have been added where applicable to indicate results of non-parametric Kruskal-Wallis test ($\alpha = 0.05$) with Steel-Dwass-Critchlow-Fligner multiple comparison ($\alpha = 0.05$); uppercase/bold letters, where applicable, indicate results of comparison among seasonal events; after Bonferroni correction for multiple comparison, only richness was significantly different among seasons (experiment-wise $\alpha = 0.05$); estuarine, transitional, and freshwater zones are synonymous with the upper estuary, transition zone, and tidal freshwater zones, respectively

Figure 8. Benthic invertebrate community metrics in the LPRSA from 2009 and 2010 sampling events

The richness of invertebrates was significantly less in the summer than in the spring (Figure 8). Similarly, Swartz's Dominance Index (SDI) was significantly less in summer 2010 than in fall 2009. After correction for multiple comparisons (i.e., Bonferroni correction, experiment-wise $\alpha = 0.05$), seasonal differences were no longer significant. This suggests that the difference in SDI among seasons is uncertain. Additional metrics of community structure (Figure 8) indicate that differences among seasons were not significant.

Deeper analysis of the 2009 and 2010 taxonomic data results in a similar conclusion, that seasonality plays a minor role in structuring the benthic invertebrate community, particularly when compared to the role of habitat conditions. For example, Figure 9 shows the results of a principal components analysis (PCA) using benthic invertebrate abundance data for the 20 most abundant taxa across all 33 sampling locations and 3 sampling events. The proximity of points in Figure 9 indicates how similar (or dissimilar, for distant points) each sampling location was to the others in terms of the abundance of dominant taxa.

Prior to analysis, the data were log-transformed and then scaled within species to give each of the species equal weighting. The PCA output for each sampling location was then labeled according to either the sampling event or the salinity zone for that location. Ellipses were then drawn around each grouping of data to show a 95% confidence limit around the average value for PC1 and PC2 (centroid) (multivariate t-distributed, $\alpha = 0.05$). Groups are significantly different if the centroid of one group is outside of the ellipse of another. As noted, Figure 9 shows that dominant benthic invertebrate species are generally similar across seasons, with the species found between the fall 2009 and summer 2010 sampling events being particularly similar.



PC – principal component

Note: Invertebrate communities sampled during each event are significantly different if the centroid (asterisk) of one group is outside of the ellipse of another. PC1 and PC2 collectively explain 60% of the variance in community structure based on the 20 most abundant taxa across all three sampling events.

Figure 9. PCA biplots of seasonal LPRSA benthic invertebrate abundance data

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DISPUTE STATEMENT ON EXPOSURE DEPTH ISSUES PERTAINING TO FATE AND TRANSPORT MODELING

LOWER PASSAIC RIVER STUDY AREA REMEDIAL INVESTIGATION/ FEASIBILITY STUDY

Section 2

Prepared for

Lower Passaic River Cooperating Parties Group

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November 2015

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LIST OF ACRONYMS AND ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo- <i>p</i> -dioxin
cfs	cubic feet per second
CFT	contaminant fate and transport
cm	centimeter
CPG	Cooperating Parties Group
CWCM	Chemical Water Column Monitoring
FFS	Focused Feasibility Study
FS	feasibility study
ft ²	square feet
LPR	Lower Passaic River
LPRSA	Lower Passaic River Study Area
m	meters
ng/kg	nanograms per kilogram
PWCM	Physical Water Column Monitoring
RI	remedial investigation
ST	sediment transport
sv-CWCM	small volume Chemical Water Column Monitoring
tetra-CB	tetrachlorobiphenyl

1 INTRODUCTION

In a June 1, 2015 letter to the Cooperating Parties Group (CPG), Region 2 of the U.S. Environmental Protection Agency (Region 2) took the position that the average contaminant concentration over the top 15 centimeters (cm) of sediment is most appropriate to represent contaminant concentrations in the benthic community exposure zone for use in the bioaccumulation model for the Lower Passaic River Study Area (LPRSA) 17-mile Remedial Investigation (RI) and Feasibility Study (FS). This topic was discussed at two meetings between the Region and the CPG in February 2014 and 2015 and the CPG had presented the case for a layer shallower than 15 cm. One of the arguments for this position is the contention that concentrations in a shallower layer, and specifically the top 2 cm of sediment, cannot be reliably calculated by the CPG's contaminant fate and transport (CFT) model, which is based on the Region's CFT model. As a result, the CPG invoked dispute resolution pursuant to paragraph 64 of the May 2007 Administrative Order on Consent on June 12, 2015, which was acknowledged by the Region on June 25, 2015. The CPG sent a letter on July 2, 2015 requesting the "additional material" that Region 2 relied upon in evaluating the CPG's work on a proposed exposure depth for the 17-mile LPRSA; the Region responded on July 9, 2015 with this information.

The Region's contention derives from three incorrect assertions made by Region 2 in the June 1 letter and in a subsequent letter dated July 9, 2015:

- Region 2 claims the CFT model computes relationships between concentrations in the 0 to 2 cm layer and the 0 to 15 cm layer that are inconsistent with measurements.
- Region 2 also claims that the CPG's sediment transport (ST) model cannot reliably predict bed elevation changes at scales as small as 2 cm.
- Region 2 claims that accurately predicting water column contaminant concentrations (i.e., matching the levels measured in the Chemical Water Column Monitoring [CWCM] program) provides no confidence in the CFT model's concentrations in the 0 to 2 cm layer.

Region 2 also contends that the CFT model's average concentration over the top 15 cm is a reasonable surrogate for the average concentration in the top 2 cm. It does so without evidence and in direct contradiction to its own model.

In this document, the CPG demonstrates why Region 2's assertions are incorrect and why it is indefensible to use the 15 cm average to represent the 2 cm average as Region 2 directs.

Section 2 explains that sediment transport and contaminant transfer are controlled by processes occurring at scales much finer than 15 cm, which is why ST and CFT models are built to represent these scales. Section 3 demonstrates the logical relationship between 0 to 2 and 0 to 15 cm concentrations in site-specific data and model predictions, which implies that the CPG model calculates realistic 0 to 2 cm concentrations. Section 4 explains that the ST model's predictions rest on its ability to realistically represent centimeter-scale bed elevation processes and its behavior at this scale is constrained by multiple datasets. Section 5 explains why the CWCM data constrain the calibration of the 0 to 2 cm concentrations. Section 6 explains that Region 2's direction to use the 15 cm average in favor of the 2 cm average is inconsistent with the model setup and predictions, and relying on it significantly biases broad-scale averages. The best estimate of the 2 cm average concentrations comes from the model predictions of this interval.

2 THE CPG'S AND REGION 2'S MODELS CALCULATE CONCENTRATIONS IN SEDIMENT AT THE SCALE OF 0 TO 2 CM BECAUSE FATE AND TRANSPORT PROCESSES OCCUR ON THIS SCALE

The Region 2 and CPG CFT models represent the top 15 cm of sediment as a stack of 1 cm thick layers. Models are constructed with such fine vertical resolution as a general practice because of the generally accepted notion that vertical gradients need to be represented. Examples beyond Region 2's Focused Feasibility Study (FFS) model and the CPG model of the Lower Passaic River (LPR), are the models developed for the Hudson River, the Grasse River, and the Fox River Superfund sites.

Hudson River: *A vertical discretization of two centimeters was used for the HUDTOX sediment segmentation to provide adequate resolution of vertical PCB profiles for simulating sediment-water interactions and long-term system responses.* (USEPA 2000, page 58)

Grasse River: *The bed model was constructed using twelve 1-inch layers to simulate PCB transport in the sediments.* (Alcoa 2010, page A4-14)

Fox River: *The upper two layers are each 2 centimeters thick and represent biologically active sediments. The third layer is 6 centimeters thick and represents biologically inactive sediments.* (HQI 2001, page 21)

Models are constructed this way because water column contaminant concentrations and long-term trends in sediment contaminant concentrations are largely controlled by contaminant concentrations in the top few centimeters of sediment. Diffusion between the bed and the water column is governed by the gradient in concentration between the water column and sediments within the top 1 cm or so. Resuspension is largely derived from the top few centimeters or less, except in extreme events. This is so because resistance to erosion increases rapidly with depth, such that erosion stops a short distance into the bed. The Region 2 analysis of SedFlume erosion measurements in the LPR concluded the critical shear stress for erosion was four times higher at 2 cm than at the surface, increasing to ten times higher at 5 cm and further still as depth increased (see Table 1; Table 3-7 of LBG et al. 2014, Appendix B II).

It seems inexplicable for Region 2 to argue that model predictions for the top few centimeters are unreliable when its model is constructed to explicitly calculate concentrations in this depth interval because they are key to being able to properly represent contaminant fate and transport. Moreover, the processes operating on these scales are constrained by calibration to the available data within both the ST model (Section 4) and the CFT model (Section 5).

3 THE PAIRED TOP 2 CM AND TOP 15 CM SEDIMENT CONCENTRATION DATA FOR CHEMICALS OF POTENTIAL CONCERN SUPPORT THE 2 CM PREDICTIONS

3.1 Region 2 Contention in the June 1 and July 9 Letters

A review of the limited dataset of finely segmented cores with contaminant concentrations from depths of less than 15 cm shows significant variability: sometimes the surface concentrations are higher than concentrations averaged over the top 15 cm and sometimes they are lower. (Region 2 June 1, 2015 letter)

... the concentration of 2,3,7,8-TCDD averaged over 15 cm compared to the concentration at the top 2 cm is highly variable. While this is not a statistically valid dataset from which to draw conclusions about 2 cm concentrations across the river, the results do suggest that there are insufficient data from the top 2 cm to evaluate model performance. (Region 2 July 9, 2015 letter)

Despite the fact that the limited data set shows high variability, based on the modeling files provided to EPA in December 2014, the CPGs modeled predictions over 2 cm are consistently lower than those predicted over 15 cm on a reach averaged basis and over the vast majority of individual grid cells in the LPRSA. Over the duration of the 1995-2013 calibration period, the CPG's model predictions of 2,3,7,8-TCDD in the top 2 cm average less than half of the concentration in the top 15 cm. Given the variability in the limited 2 cm data set, EPA does not have confidence in these modeling results; they would need to be verified through the collection of additional data. (Region 2 July 9, 2015 letter)

3.2 Cooperating Parties Group Response

The CPG disagrees with Region 2's contention that the CPG CFT model exhibits behavior inconsistent with the available 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) data relating 2 cm average and 15 cm average concentrations. Additionally, the models are sufficiently calibrated for the various processes that govern this behavior such that the validity of the model results can be judged in the absence of additional measurements of 2 cm average concentrations.

While Region 2 is correct in stating “the concentration of 2,3,7,8-TCDD averaged over 15 cm compared to the concentration at the top 2 cm is highly variable,” it failed to recognize that the variability is explainable, consistent with the conceptual model of the site and with the CPG CFT model predictions. Rather than being evidence against reliance on model predicted 2 cm averages, these data support such reliance.

A structure emerges when the relationships between 2 cm average and 15 cm average concentrations are examined more closely than was done by Region 2.¹ The ratio of these concentrations in individual samples decreases with increasing 15 cm average concentration (Figure 1). The highest ratio (3.6) is at the lowest 15 cm concentration (10 nanograms per kilogram [ng/kg]), the second highest ratio (1.6) is at the next lowest 15 cm concentration (98 ng/kg), and the lowest ratio (0.2) is at the highest 15 cm concentration (4,134 ng/kg). The ratio averages 0.9 for the six samples with 15 cm concentrations in the range of 200 to 500 ng/kg.

Displaying the model results in the same format as Figure 1, Figures 2a and 2b show that the model generates the same trend as the data and is numerically consistent with the data for both 2,3,7,8-TCDD and tetrachlorobiphenyl (tetra-CB), respectively, which is evident comparing the red dots (data) to the black dots (model). Thus, the model is calculating realistic relationships between 2 cm and 15 cm concentrations, which supports its use to set exposure concentrations for the bioaccumulation model.

The model’s vertical profiles have an intuitive structure that is evident in the average profiles for individual depositional regimes (Figures 3a and 3b). Areas that are strongly depositional over the long-term calibration period (greater than 1 cm/year) exhibit a nearly constant concentration from the surface to 15 cm. This condition results in a ratio of the 2 cm average to the 15 cm average approaching 1 (i.e., no vertical gradient), because sediments throughout the upper 15 cm reflect fairly recent deposition. In contrast, areas that are erosional or non-depositional exhibit a gradient with higher concentrations at depth and ratios of

¹ In addition to the eight finely segmented cores Region 2 selected, one core (G0000181 collected under 2007-2008 Sediment Sampling Program), with a surface slice of 2.5 cm located near the mouth of the LPR, was included in this analysis.

approximately 0.4 for both 2,3,7,8-TCDD (Figure 3a) and tetra-CB (Figure 3b), because high legacy concentrations have not been buried below 15 cm.

The behavior of the model and the data are consistent with the measurements of 2,3,7,8-TCDD concentrations on water column particulate matter and recently deposited material. These concentrations reflect concentrations in the top few centimeters of sediment because that is the primary contemporary source of 2,3,7,8-TCDD to the water column. They are typically a few hundred ng/kg (Table 3-8 of LBG et al. 2014, Appendix B II; Figure 4-3 of LBG et al. 2014, Appendix C; Figure 6-5a of Anchor QEA et al. 2015). Therefore, the 2 to 15 cm concentration ratio should generally be close to one when 15 cm concentrations are a few hundred ng/kg. It should generally be higher at lower concentrations and lower at higher concentrations. This behavior is shown by both data (Figure 1) and model (Figures 2 and 3).

Region 2's distrust of a vertical gradient in the upper 15 cm mean concentration is puzzling given that its FFS model produces even stronger vertical gradients than the CPG model (Figures 4a and 4b), and these gradients played a central role in Region 2's initialization and calibration of the FFS model. In particular, Region 2 imposed a vertical gradient on the model initial conditions for the upper 15 cm because "after running the model initially ... the sediments developed a gradient over the top 15 cm (~6 in). This gradient is controlled mainly by the rate of particle mixing within the bed" (LBG et al. 2014). Vertical gradients in areas of high 0 to 15 cm concentration are unavoidable unless one homogenizes the 0 to 15 cm interval (e.g., by imposing intense sediment mixing), which would lead to excess contaminant depletion at the sediment-water interface and an unrealistic rapid decline in the 0 to 15 cm average concentration (based on the CPG's experience).

The CPG also disagrees with Region 2's contention that the 0 to 2 cm concentration "would need to be verified through the collection of additional data" before they can confidently be used. The vertical profile predicted by the model is a logical consequence of the contaminant mass balance and the well-accepted contaminant fate and transport processes underlying the model structure, which are constrained by joint calibration to the 15 cm sediment bed data and the water column data. The vertical structure that forms in the sediment bed over the top 15 cm is the result of net chemical sources and sinks acting at the surface (water column

interaction) and at the bottom of this interval (interaction with deeper sediments below 15 cm), as well as internal redistribution (mixing). The net sources and sinks acting at the surface are constrained by the CWCM data because net mass entering and leaving the bed at the surface determines the water column concentrations. The overall average 15 cm concentrations are constrained by the sediment bed data. Having a model with deterministic physical processes calibrated to both the average of the structure (15 cm average) and the net sinks or sources at the surface produces a constrained vertical structure. Although Region 2 has challenged the value of the CWCM data to the CPG calibration, the principle of simultaneously calibrating the bed and the water column is not controversial and has been implicitly agreed on by Region 2 and the CPG since the start of the modeling effort; this is demonstrated by the *Modeling Work Plan* (HQI 2006) and the data use objectives of the small volume CWCM (sv-CWCM) program (AECOM 2011). The need to adequately specify the vertical profile of contaminants and the concentrations near the sediment water interface is implicit in requiring that a model reproduce water column fluxes. The CPG does not disagree that more data on near surface sediments would be useful; however, the absence of additional data does not disqualify the use of 0 to 2 cm concentrations from the model that have been calibrated in the manner envisioned throughout the RI/FS process.

Further support for using the model results for the 2 cm average comes from comparing those results to measured 2 cm average concentrations. A larger dataset² exists for 2 cm concentrations than for the dataset of matched 2 and 15 cm concentrations. Figure 5 compares 2 cm 2,3,7,8-TCDD and tetra-CB concentrations within the LPR measured in the late-2000s to values computed by the model for the matching grid cells. Exact comparability is not expected for several reasons; for instance, a spatial average over the area of a model cell is being compared to a point measurement within that area. The degree of comparability that exists is similar to the level of calibration for the 15 cm concentrations in Region 2's FFS model.

² In addition to the Region 2 selected eight 0 to 2 cm samples from the 2008 CPG Low-resolution Coring Program, samples with a 0 to 2.5 cm interval from the 2007-2008 Sediment Sampling Program and the 2007 U.S. Environmental Protection Agency Empirical Mass Balance Model Program were included in the analysis.

4 THE VALIDITY OF SEDIMENT TRANSPORT COMPUTED ON THE SCALE OF CENTIMETERS IS SUPPORTED BY THE PERFORMANCE OF THE SEDIMENT TRANSPORT MODEL

4.1 Region 2 Contention in the June 1 and July 9 Letters

The sediment transport model has been calibrated using the bathymetry change dataset, the accuracy of which is a direct function of the uncertainties of the individual bathymetry datasets ... (Region 2 June 1 and July 9, 2015 letters)

The existing bathymetry change dataset cannot resolve changes as finely as 2 cm, due to factors including instrument accuracy and changes in surface sediment density (i.e., reflectiveness). (Region 2 July 9, 2015 letter)

... which means that the model cannot reliably predict bed elevation changes at scales as small as 2 cm. This means that there is no way to determine if the solids calculated to be present in the top 2 cm are, in fact, present in a particular grid cell or present but buried by subsequent deposition. Since the contaminant fate and transport model's predictions of contaminant concentrations are driven by bed characteristics passed to it by the sediment transport model, this inability to reliably predict bed elevation changes at 2 cm scales would further add to the uncertainty in the predicted contaminant concentrations in the 2 cm layer. The contaminant fate and transport model cannot be expected to produce reliable estimates of contaminants present in the top 2 cm if the sediment transport model cannot produce reliable estimates of the solids transport at this high level of vertical resolution. (Region 2 July 9, 2015 letter)

4.2 Cooperating Parties Group Response

Sediment transport in the LPR and most other sites is modeled using centimeter-scale resolution and models depend on the reliability at this scale to accurately represent the system being modeled.

Erosion processes typically occur on the scale of a few centimeters. Region 2 recognizes this and constructed its sediment transport model with critical shear stresses for the initiation of erosion and erosion rates at various shear stresses that decline greatly moving centimeters

into the bed. This can be seen in Table 3-7 of the Region 2 FFS sediment transport model report (LBG et al. 2014, Appendix B II), which is reproduced here as Table 1. Representing these gradients is necessary because erosion and deposition occurring in most events are restricted to the top few centimeters.

To demonstrate this fact, the average erosion depths calculated by the CPG sediment transport model for a range of high flow events are presented in Figure 6. For events with peak flow less than 10,000 cubic feet per second (cfs) (i.e., corresponding to a return period of just under 5 years), the cells experiencing erosion have on average less than 1 cm of erosion. Only the single largest event (Hurricane Irene) over the calibration period has an average greater than a few centimeters.

It is puzzling that Region 2 would claim that the ST model is unreliable on the scale of several centimeters, given that both the Region 2 and CPG CFT models rely on the ability of the ST model to predict centimeter-scale processes that govern water column contaminant levels and long-term trends in sediment contaminant levels.

Region 2 ignores the fact that the bathymetric change dataset is only one of several types of data used to calibrate the ST model. It has been calibrated to the solids fluxes and suspended solids concentrations at various locations in the LPR and over various events and to surficial bed sediment composition from various datasets. Calibrating to multiple metrics and events ensures that surface sediment dynamics, which occur on the centimeter-scale, are reasonably represented and that bathymetric changes resulting from these dynamics, which also occur on the centimeter-scale for much of the river, are reasonably predicted at the spatial resolution of the model.³ Among these calibration checks are the long-term burial rates, which overall are on the order of centimeters per year. Both the Region 2 and CPG models are able to reasonably replicate the rates obtained from measurements.

³ The sub-grid scale variability does not invalidate the predictions at the scale represented by the model and is a factor affecting all models of natural phenomena. Moreover, sub-grid scale processes affect all aspects of the modeling and the 2 cm layer is not unique in this regard.

The model's capability in capturing the dynamics at the sediment surface can be seen in its response as it transitions from conditions when one process (erosion) predominates, to conditions when both erosion and deposition occur in the LPR. This response during and following large storm events is shown on the right side of Figure 6. During such events, given the above-average currents and shear stresses in the LPR, the model erodes through the more erodible surficial sediment layers until it exposes a sediment layer with shear strength greater than the imposed shear stress. Following the storm event, under more quiescent conditions when shear stresses are lower, any erosion in such areas can only occur from sediments deposited following the storm event (which presumably have less shear strength than the underlying sediments exposed during the storm). Therefore, the model's ability to reproduce the surficial sediment dynamics of erosion and deposition is essential to reproducing the suspended sediment dynamics following the storm event. These processes and the performance of the model can be seen in its comparisons to: 1) the data from a 16,000 cfs event in March 2010 (an event with a return period of 25 years; documented in Section 5.4.2. of Appendix M of the RI Report; Anchor QEA et al. 2015); and 2) the data from the Spring 2010 Physical Water Column Monitoring (PWCM) survey in the LPR, which commenced shortly after the high-flow event of March 2010 (documented in Section 5.4.3 of Appendix M of the RI Report; Anchor QEA et al. 2015). The comparisons show that the model performs reasonably in reproducing the measurements during the predominantly erosional conditions associated with the storm event, as well as the measurements reflecting erosional and depositional processes during the relatively lower flow conditions following the storm event. If the model was limited in its ability to reproduce the surficial sediment dynamics, then it would also be limited in its ability to reproduce the measurements during the spring 2010 survey. Therefore, these comparisons provide a measure of confidence in the model's ability to reproduce the surficial sediment dynamics.

Moreover, Region 2 is wrong in stating that bathymetric change estimates are too imprecise to be used to calibrate sediment transport at the 2 cm scale. Both its FFS ST model and the CPG ST model have used them for this purpose, and appropriately so. Region 2's assertion comes from considering only the accuracy of individual bathymetry measurement points, not the accuracy of averages of those measurements over the area of a model grid element. An average of the individual measurements has greater accuracy than the measurements

themselves. As explained below, the average elevations within each model grid cell are known with sufficient accuracy sub-centimeter precision and provide a way to check model predictions of elevation change on the scale of the 2 cm layer at issue.

The greater accuracy of average bed elevation comes from the well-known fact that the variance of that average is the variance of the individual independent measurements divided by the number of measurements.

Suppose individual measurements have a variance of 10 cm² (which means a standard deviation of 3.2 cm and a 95th percentile uncertainty of 13 cm; reasonable uncertainty for multi-beam measurements), the variance of the average of 100 measurements is 0.1 cm (i.e., 10/100) and the 95th percentile uncertainty is 1.3 cm, ten times less than the individual measurements. This impact of averaging is illustrated in Figure 7.

Multibeam data exist at a resolution of 1 square foot (ft²), which means that 100 measurements are obtained in a 10-foot by 10-foot area. The high accuracy at this scale relative to each measurement is the reason that evaluations of cutline elevations and backfill elevations on the Hudson River dredging project are done at this scale. Those evaluations require accuracy of a few centimeters to assess attainment of the required dredge depth while minimizing unnecessary over-dredging.

The grid elements in the CPG sediment transport model have a typical size of 60 meters (m) by 180 m (RI Report Appendix K; Anchor QEA et al. 2015), which equates to an area of 116,000 ft². If each measurement had a 13 cm uncertainty band, the uncertainty band of the average of the 116,000 elevation measurements would be 0.05 cm.

Achievement of this accuracy is evident comparing model grid element bed elevation averages calculated from 2007 and 2008 bathymetric surveys. Because no significant high flow events occurred between these surveys, large changes in bed elevation are not expected (except in some highly depositional areas and in the vicinity of structures that induce secondary flows). The grid cell averages should mostly be very similar. That is the case as can be seen in Figure 67 from Appendix M of the RI Report (Anchor QEA et al. 2015). The data shown in that figure are presented here as a frequency plot (Figure 8). Approximately

35% of the grid cells had essentially identical elevations (less than 2 cm different) and approximately 70% had differences less than 5 cm.

5 THE CWCM DATA CONSTRAIN AND VALIDATE MODEL PREDICTIONS OF 0 TO 2 CM SEDIMENT CONCENTRATIONS

5.1 Region 2 Contention in the July 9 Letter

EPA disagrees with the CPG's assertion that the water column contaminant data provide a constraint on the 2 cm bed concentrations, because the water column concentrations are controlled by contaminant concentrations in the fluff layer and the CPG's model includes a parameter to control the transfer of contaminants between the upper layer of the bed and the fluff layer. The combination of the transfer parameter and contaminant concentrations in the upper layer of the bed (below the fluff layer) control contaminant flux to the water column. This provides a non-unique link between the water column and the bed below the fluff layer. While alternate combinations of bed concentrations and transfer parameters could reproduce water column contaminants equally well, the bioaccumulation model would be affected by these alternate choices. (Region 2 July 9, 2015 letter)

5.2 CPG Response

As noted in Section 3, the Region 2-authored LPR/Newark Bay Modeling Work Plan (HQI 2006) envisioned the need for water column data to calibrate the model's flux of contaminants between the bed and the water column (HQI 2006). This need is expressed in the objectives in the Region 2-approved sv-CWCM Program Quality Assurance Project Plan (AECOM 2011; "... the data provide information to develop the inputs to the model and to characterize the transport of contaminants in the LPRSA and NBSA, including the preliminary calibration of the flux of contaminants from the sediments to the water column through routine monitoring events").

The contaminant flux to the water column is controlled by the near-surface bed contaminant concentration and the solids flux. The Region 2 and CPG models are conceptually consistent in this regard; however, the CPG model offers a more refined representation that includes a fluff layer. The model tracks the contaminant within this millimeter-scale layer so as to prevent unrealistic contaminant mixing between depositing particles and underlying sediments over the short time scale of a tidal cycle. Although the interaction between the water column and the parent bed is influenced by the fluff layer, the water column flux is still controlled by the concentrations in the surface of the parent bed and the transfer of

contaminants between that layer and the fluff layer, and the parent bed interacts directly with the water column if the fluff layer is not present, as during erosion events.

The “parameter to control the transfer of contaminants between the upper layer of the bed and the fluff layer” (Region 2 July 9, 2015 letter) was calibrated to the CWCM data and resulted in a calibration value equivalent to the sediment mixing intensity for both 2,3,7,8-TCDD and tetra-CB. This value is calibrated to the sediment 15 cm average and is well within literature values (Table 1 of Appendix K in CPG RI Report; Anchor QEA et al. 2015; Boudreau 1994; Thoms et al. 1995; Olsen et al. 1981).

The logical coupling between 2 cm concentrations and water column concentrations can be demonstrated by increasing the parent bed and fluff layer exchange. Increasing the rate of contaminant exchange between the parent layer and the fluff layer such that parent layer and fluff concentration approach one another (essentially no fluff layer), causes the mean 2 cm concentrations to decline compared to the calibration (shown for 2,3,7,8-TCDD in Figure 9; blue versus orange line). The contaminant mass that is lost from the bed appears as an over-predicted water column response and the quality of the water column calibration declines (the “model-to-data residual” [see Appendix K, Section 4.1.1, of Anchor QEA et al. 2015] increases 320% compared to the calibrated value for 2,3,7,8-TCDD; a larger value is a lower quality calibration). Various combinations of parameter values could provide a quality calibration; however, it is the CPG’s experience examining alternative combinations that the 2 cm mean concentrations remain similar when constrained by both the 15 cm sediment data and the CWCM data.

6 THE CFT MODEL'S 0 TO 15 CM AVERAGE CONCENTRATIONS ARE POOR SURROGATES FOR THE 0 TO 2 CM CONCENTRATIONS

6.1 Region 2 Contention in the June 1 Letter

A review of the limited dataset of finely segmented cores with contaminant concentrations from depths of less than 15 cm shows significant variability: sometimes the surface concentrations are higher than concentrations averaged over the top 15 cm and sometimes they are lower. If these data suggest anything, it is that a 15 cm composite reasonably represents concentrations at shallower depths. (Region 2 June 1, 2015 letter)

It is EPA's position that the existing RI data from the top 6 inches (approximately 15 cm) of sediment, and model concentration simulation results for this depth interval, should be used to represent contaminant concentrations for this parameter [exposure depth]. (Region 2 June 1, 2015 letter)

6.2 Cooperating Parties Group Response

Region 2 is invoking model uncertainty as a reason in and of itself to support the use of 0 to 15 cm as the exposure depth, implying that this directive should stand even though “varying depths of benthic community exposure zone less than 15 cm may be appropriate for parts of the LPRSA” (Region 2 July 9, 2015 letter).

Region 2 is thereby arguing that the model's prediction of the 15 cm average is a better predictor of the 2 cm average concentration than the model's actual prediction of the 2 cm average. The CPG finds this argument to be unreasonable for several reasons:

- The CPG model's 0 to 2 cm concentrations are constrained and reasonable, as detailed in the preceding sections. The model was designed to resolve processes on this scale, and the model's 0 to 2 cm concentration is the best predictor available.
- Both the Region 2 and CPG models predict vertical gradients that make the 15 cm average different in most cases from the 2 cm average. In areas that are non-depositional or erosional, the 15 cm average is considerably higher and thus averages that include such areas will be biased high if the 15 cm concentration is used as a surrogate for the 2 cm concentration. This fundamental result is expected due to the

well-established processes upon which the model is based, and is unavoidable via calibration.

- Using the 15 cm average implies a paradoxical set of assumptions whereby the assumed exposure depth (15 cm) exceeds the model's present mixing depth (10 cm), which is physically not possible because biota would be exposed to contaminants that they cannot access (as noted by the CPG in its comments to Region 2 on the FFS model). At a minimum, the model would have to be recalibrated to allow mixing down to 15 cm. Calibration may be possible if the mixing were slow enough to prevent unrealistic depletion of the 15 cm average; however, this case would still result in a strong vertical gradient in the average concentration during baseline conditions such that the 15 cm average would remain a poor and biased surrogate for the 2 cm average.

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TABLES

Table 1
Parent Bed Erosion Rates for Cohesive Areas

Top (cm)	0	2	5	10	15	20	45	70
Bottom (cm)	2	5	10	15	20	45	70	320
Thickness (cm)	2	3	5	5	5	25	25	250
Tau (dyn/cm²)	Erosion Rate (cm/s)							
2	8.27E-05	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09
4	5.79E-04	8.38E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09
8	2.63E-03	7.67E-05	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09
16	1.03E-02	5.50E-04	3.37E-05	3.91E-06	2.28E-06	2.10E-06	2.07E-06	2.07E-06
32	3.82E-02	2.52E-03	3.31E-04	1.35E-04	1.18E-04	1.16E-04	1.16E-04	1.16E-04
64	1.37E-01	9.94E-03	1.65E-03	8.20E-04	7.43E-04	7.33E-04	7.32E-04	7.32E-04
128	4.83E-01	3.67E-02	6.70E-03	3.57E-03	3.27E-03	3.24E-03	3.23E-03	3.23E-03
tau crit	1.0	4.0	9.7	13.4	14.0	14.1	14.1	2000.0

Notes:

cm = centimeter

cm/s = centimeters per second

dyn/cm² = dyne per square centimeter

Source: Table 3-7 of LBG et al. (2014), Appendix B II.

FIGURES

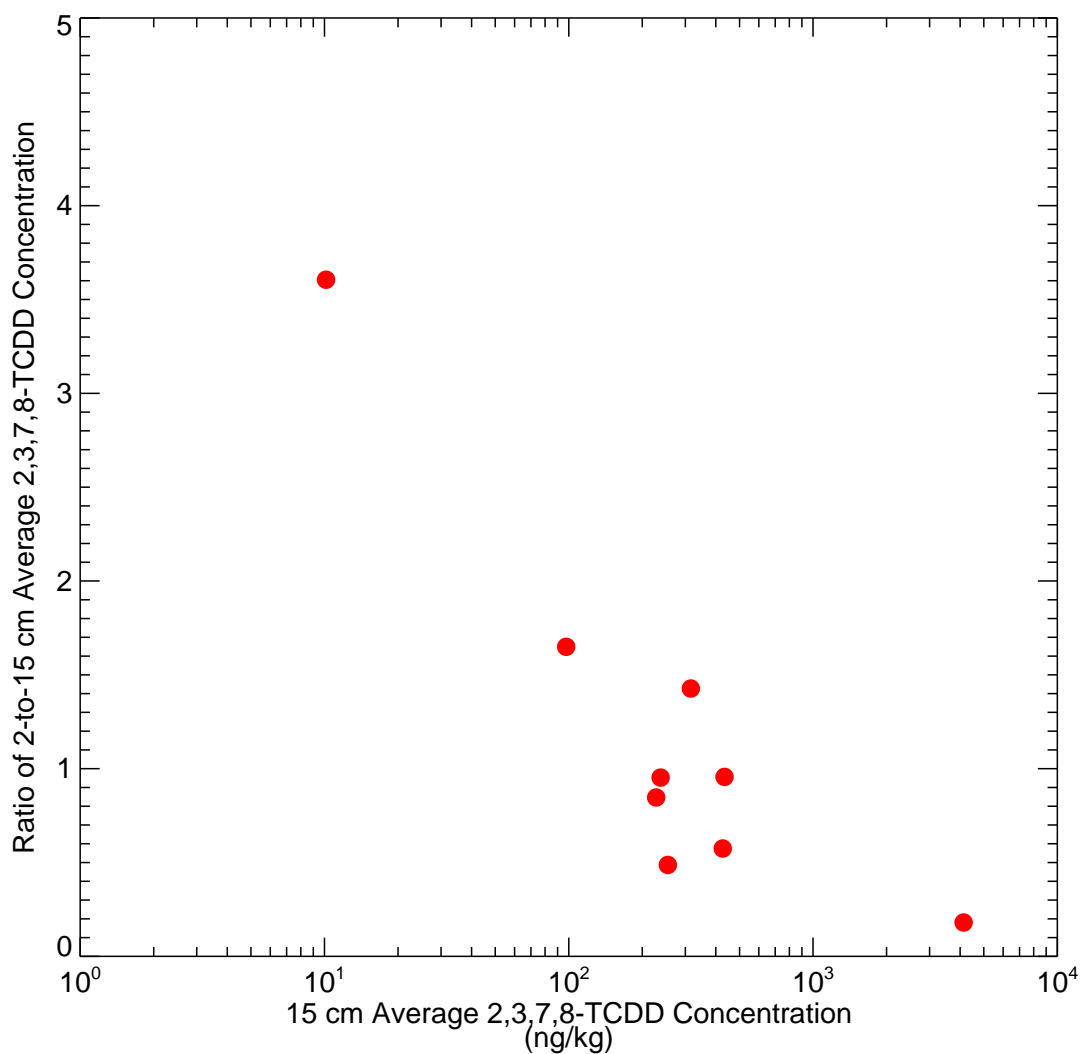


Figure 1

Measured 2 cm and 15 cm Average Concentration Ratio
Versus 15 cm Average Concentration for 2,3,7,8-TCDD
Exposure Depth Dispute Resolution

Eight Region 2 selected CPG finely segmented cores and one core from 2007-2008 sediment sampling program are shown.

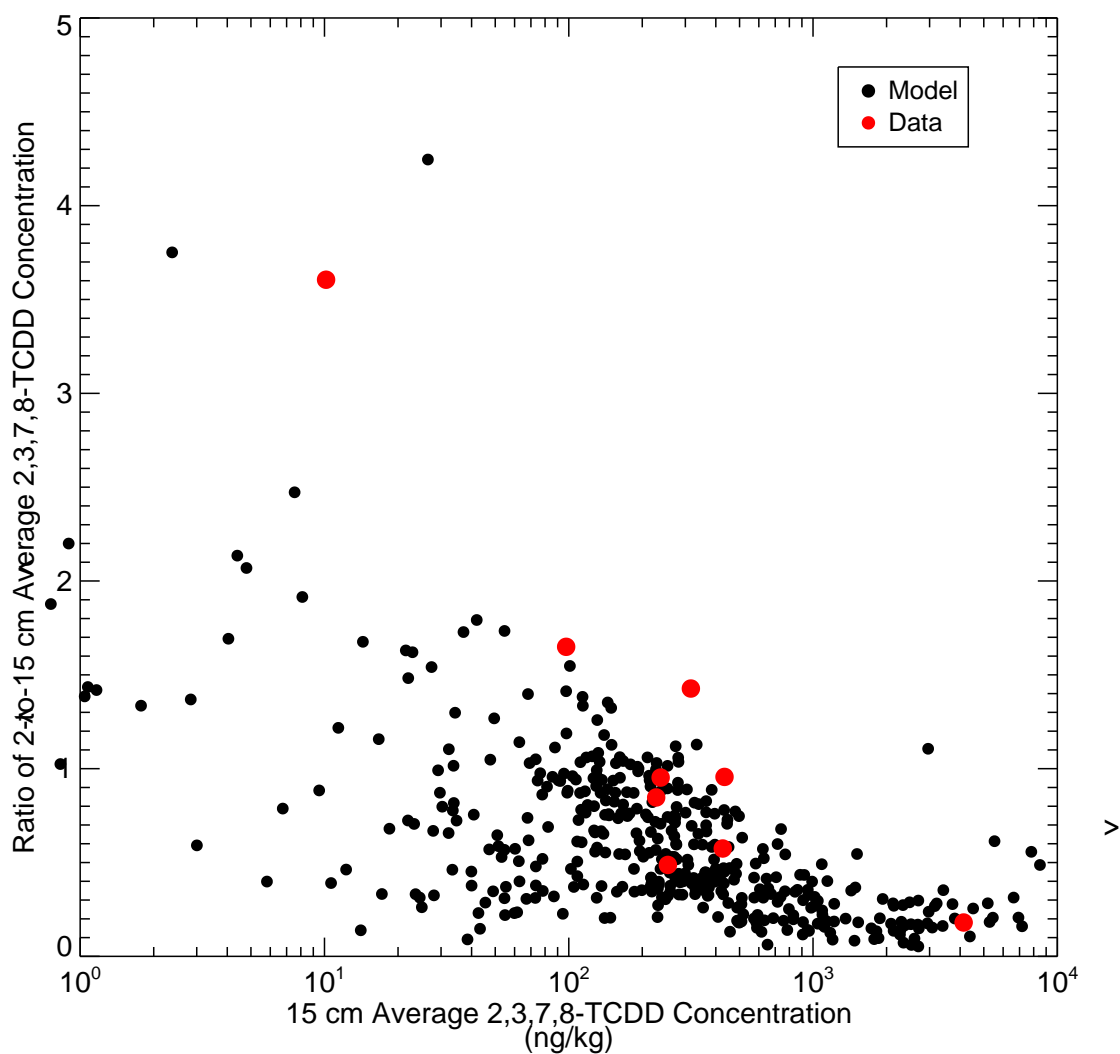


Figure 2a

Model Calculated and Measured 2 cm and 15 cm Average Concentration Ratio
Versus 15 cm Average Concentration for 2,3,7,8-TCDD
Exposure Depth Dispute Resolution

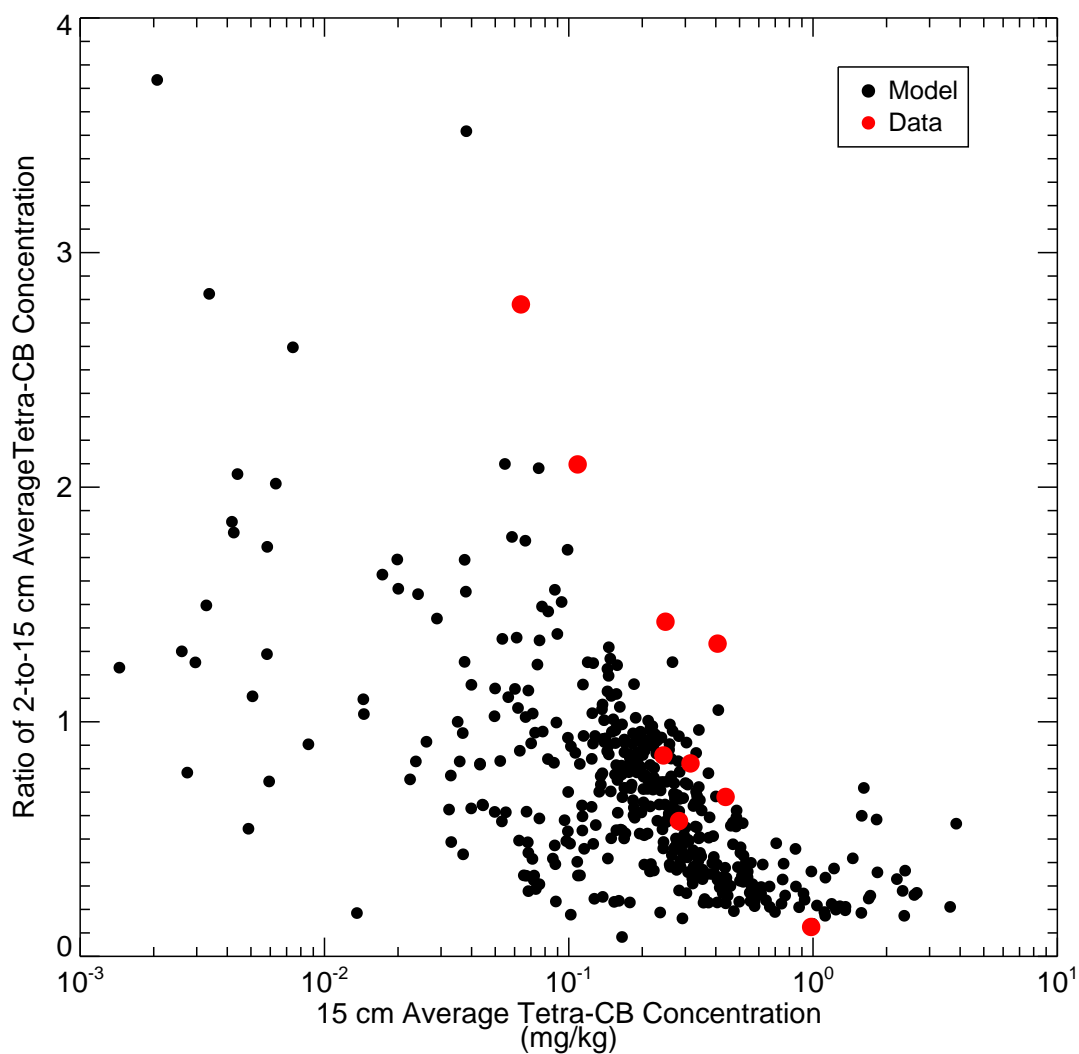


Figure 2b

Model Calculated and Measured 2 cm and 15 cm Average Concentration Ratio
Versus 15 cm Average Concentration for Tetra-CB
Exposure Depth Dispute Resolution

Model run: LPR_Tetra_long_1410-07

Model 2 cm concentrations computed as length-weighted averages of top 2 layer results
Model results were averaged annually from WY0809 within RM0-14. Ratio computed from averaged concentrations.

SM - N:\Projects\Passaic_CPG\ANALYSIS\exposure_depth\idl\foodchain_cells_exposure_depth_analysis_annual_depth_wt_modelavg_wdata.pro

Tue Sep 08 17:58:25 2015

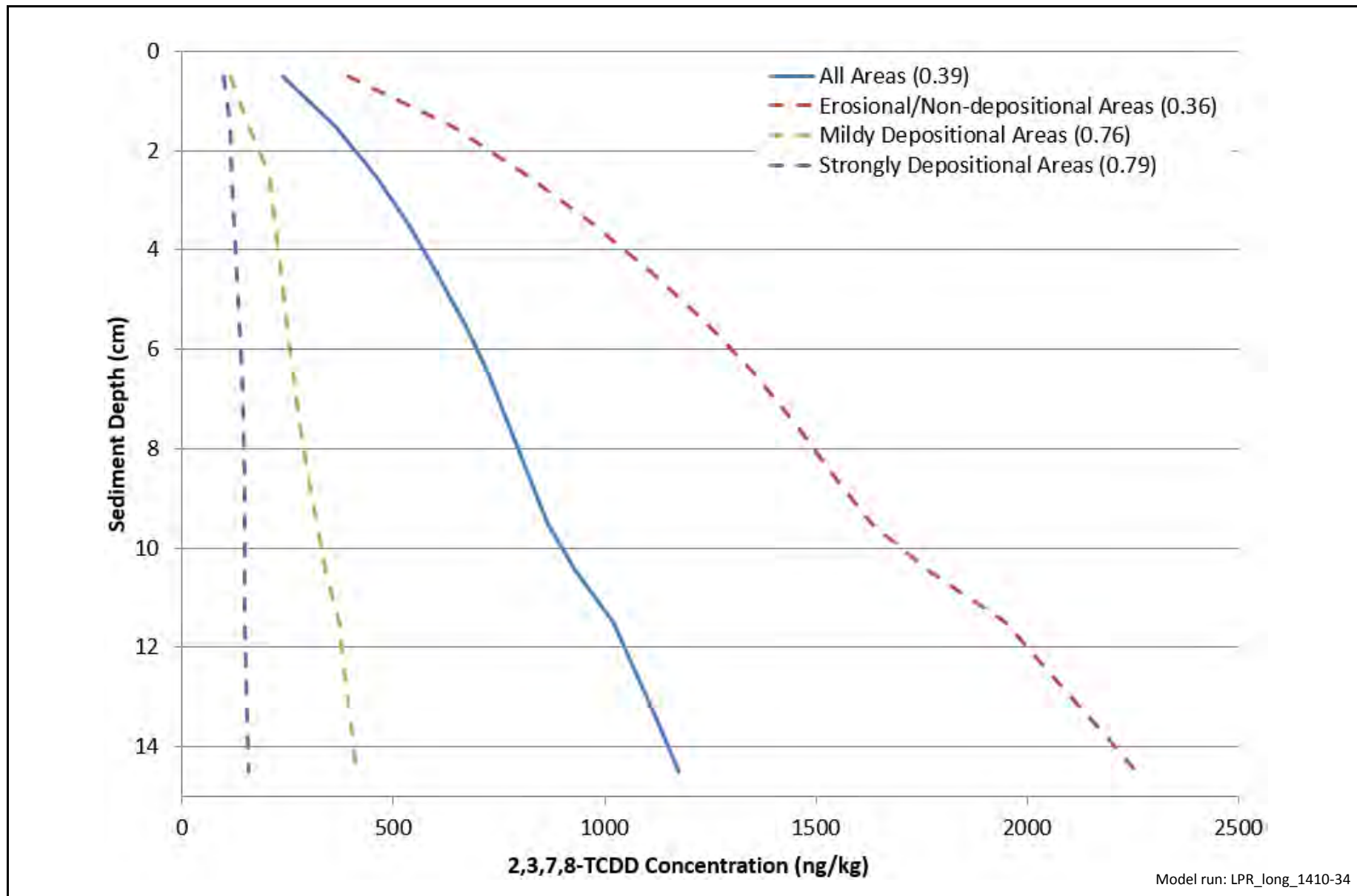


Figure 3a
Vertical Profiles of Model Calculated Average 2,3,7,8-TCDD Concentration in RM 0-8 at the End of WY 2010
Exposure Depth Dispute Resolution
Sediment layer 1 shown as 1 cm for plotting purposes. Values posted in the legend represent 2 cm to 15 cm average concentration ratios.

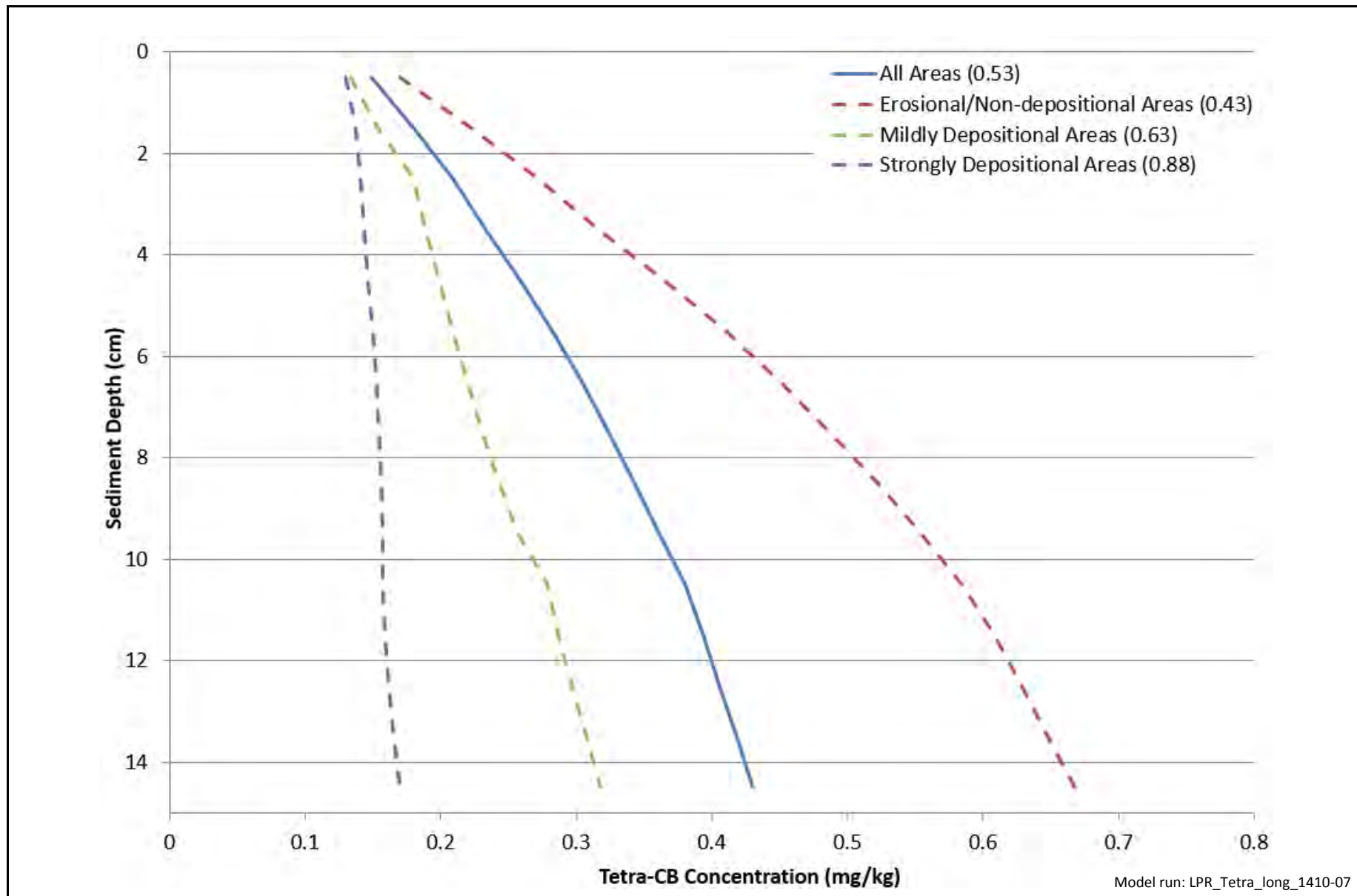


Figure 3b
Vertical Profiles of Model Calculated Average Tetra-CB Concentration in RM 0-8 at the End of WY 2010
Exposure Depth Dispute Resolution
Sediment layer 1 shown as 1 cm for plotting purposes. Values posted in the legend represent 2 cm to 15 cm average concentration ratios.

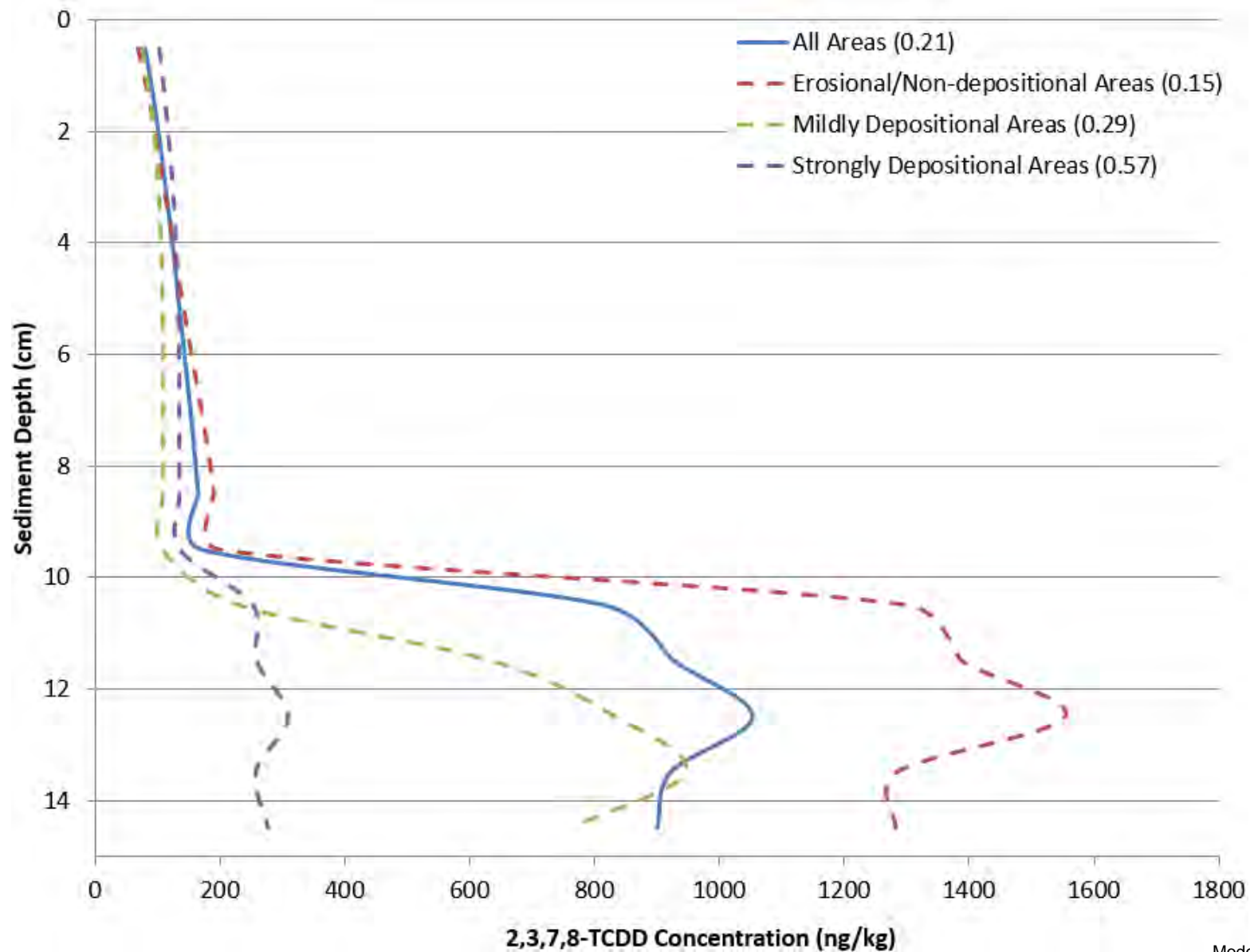
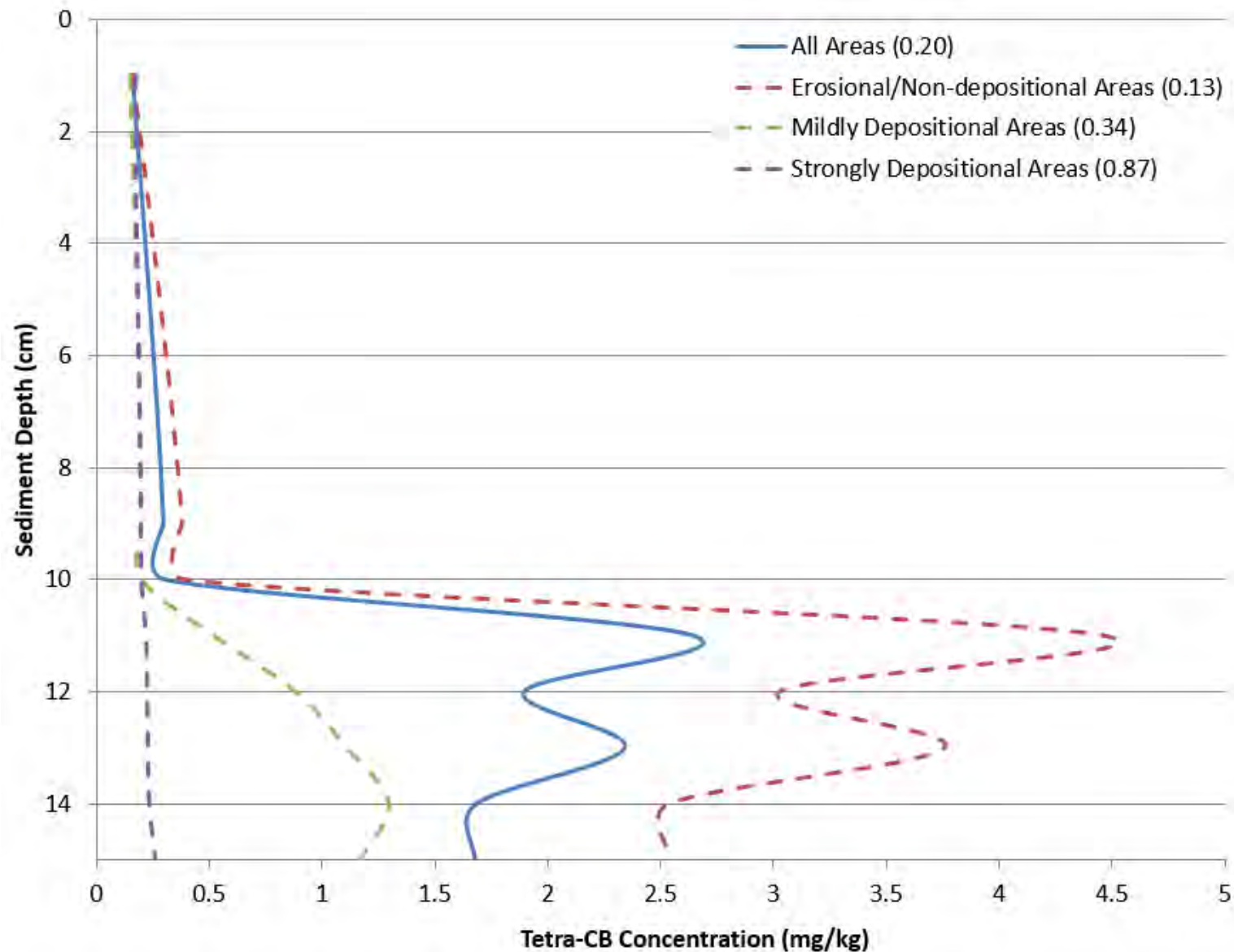


Figure 4a
 Vertical Profiles of Region 2 FFS Model Calculated Average 2,3,7,8-TCDD Concentration in RM 0-8 at the End of WY 2010
 Exposure Depth Dispute Resolution
Sediment layer 1 shown as 1 cm for plotting purposes. Values posted in the legend represent 2 cm to 15 cm average concentration ratios.



Model run: USEPA MNR

Figure 4b
 Vertical Profiles of Region 2 FFS Model Calculated Average Tetra-CB Concentration in RM 0-8 at the End of WY 2010
 Exposure Depth Dispute Resolution

Sediment layer 1 shown as 1 cm for plotting purposes. Values posted in the legend represent 2 cm to 15 cm average concentration ratios.

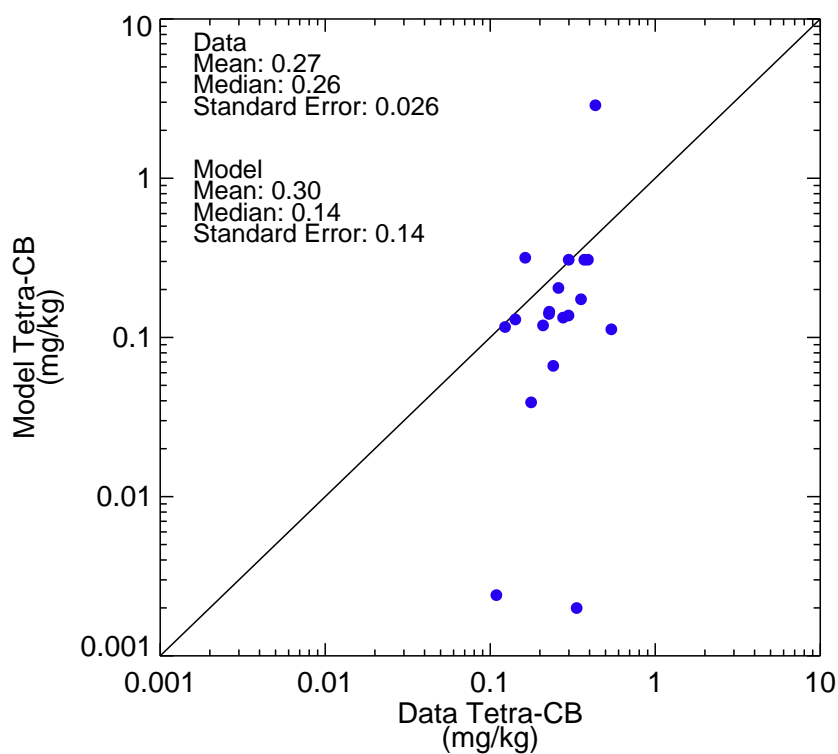
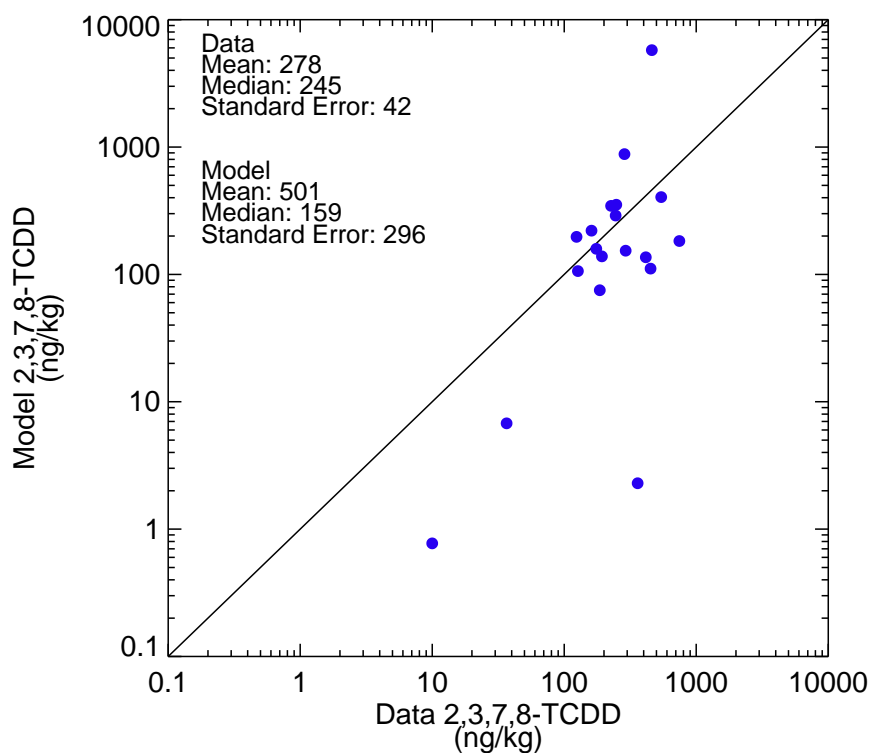


Figure 5

Model Calculated Versus Measured 2 cm Concentration for 2,3,7,8-TCDD and Tetra-CB
Exposure Depth Dispute Resolution

Model results are matched to the closest sample collection time.
Model 2 cm concentrations computed as length-weighted averages of top 2 layer results
Eight Region 2 selected CPG finely segmented cores, nine 2007 USEPA EMBM cores,
and two cores from 2007-2008 sediment sampling program are shown.
TCDD model run: LPR_long_1410-34. Tetra-CB Model Run: LPR_Tetra_long_1410-07

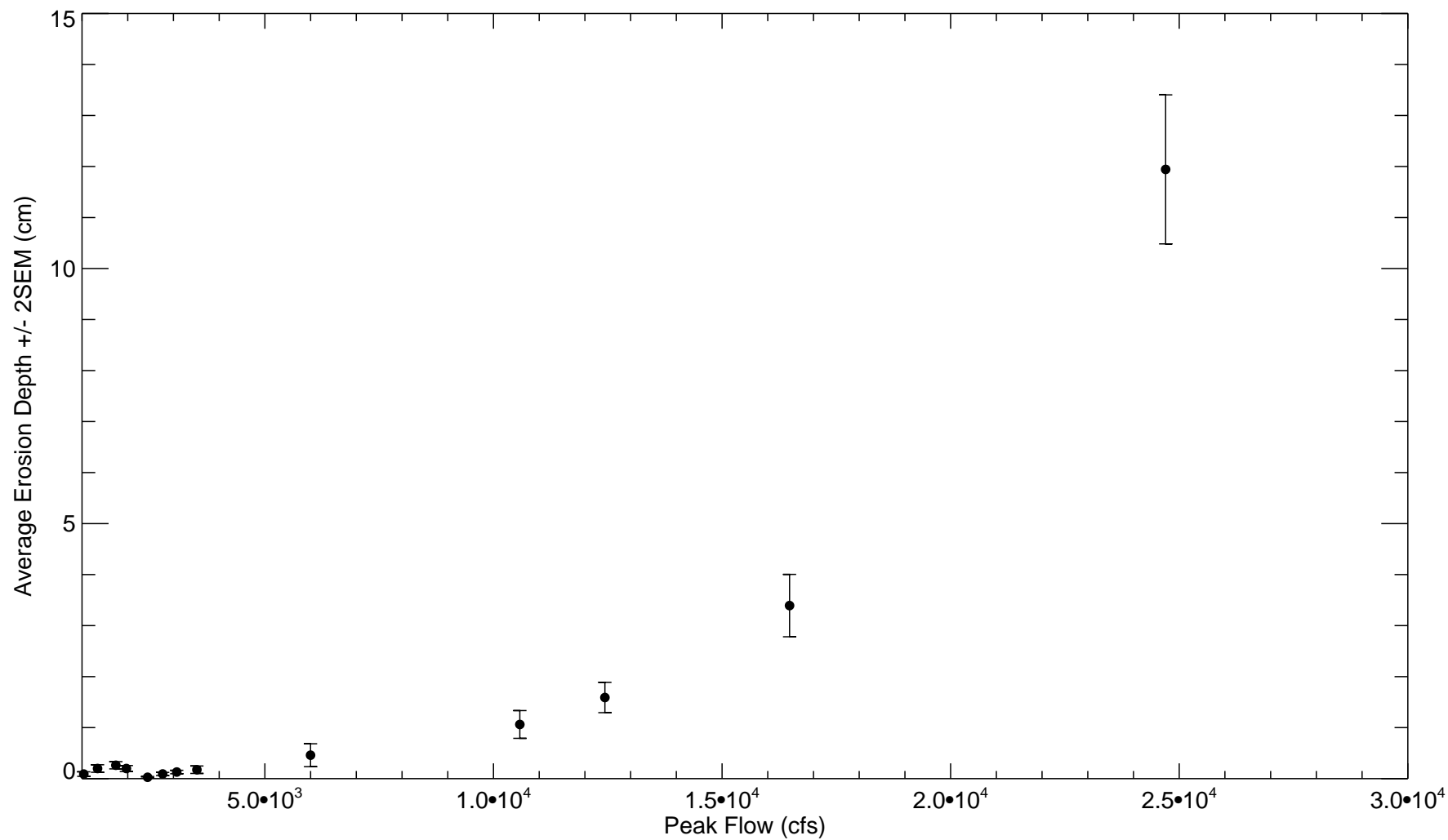


Figure 6
Average Erosion Depth Over Cells Experiencing Erosion by High Flow Events
Exposure Depth Dispute Resolution
Results were analyzed from 12 of the calibration years.

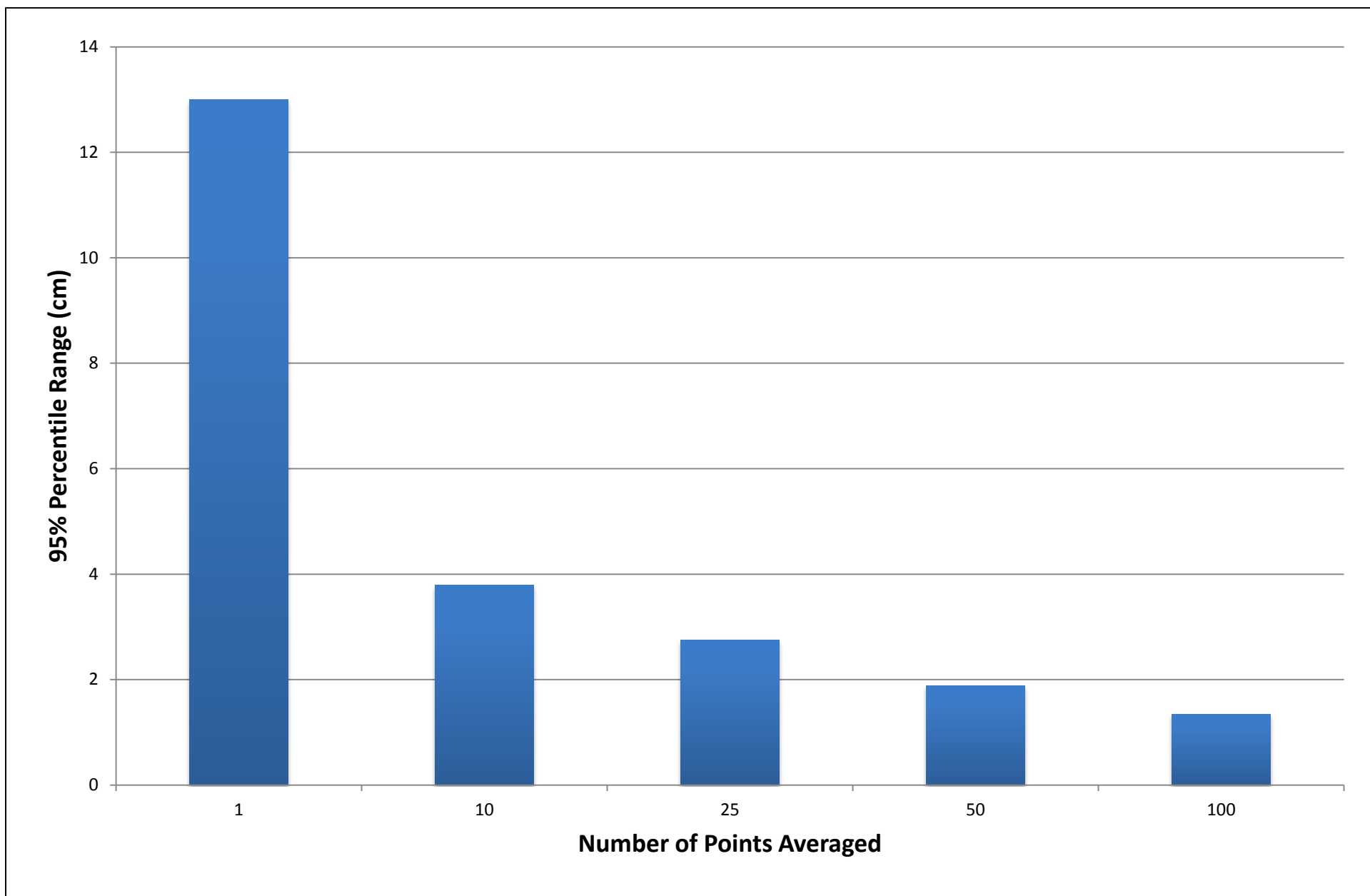


Figure 7
Illustration of Decrease in Uncertainty as a Result of Averaging Larger Numbers of Individual Measurements
Exposure Depth Dispute Resolution

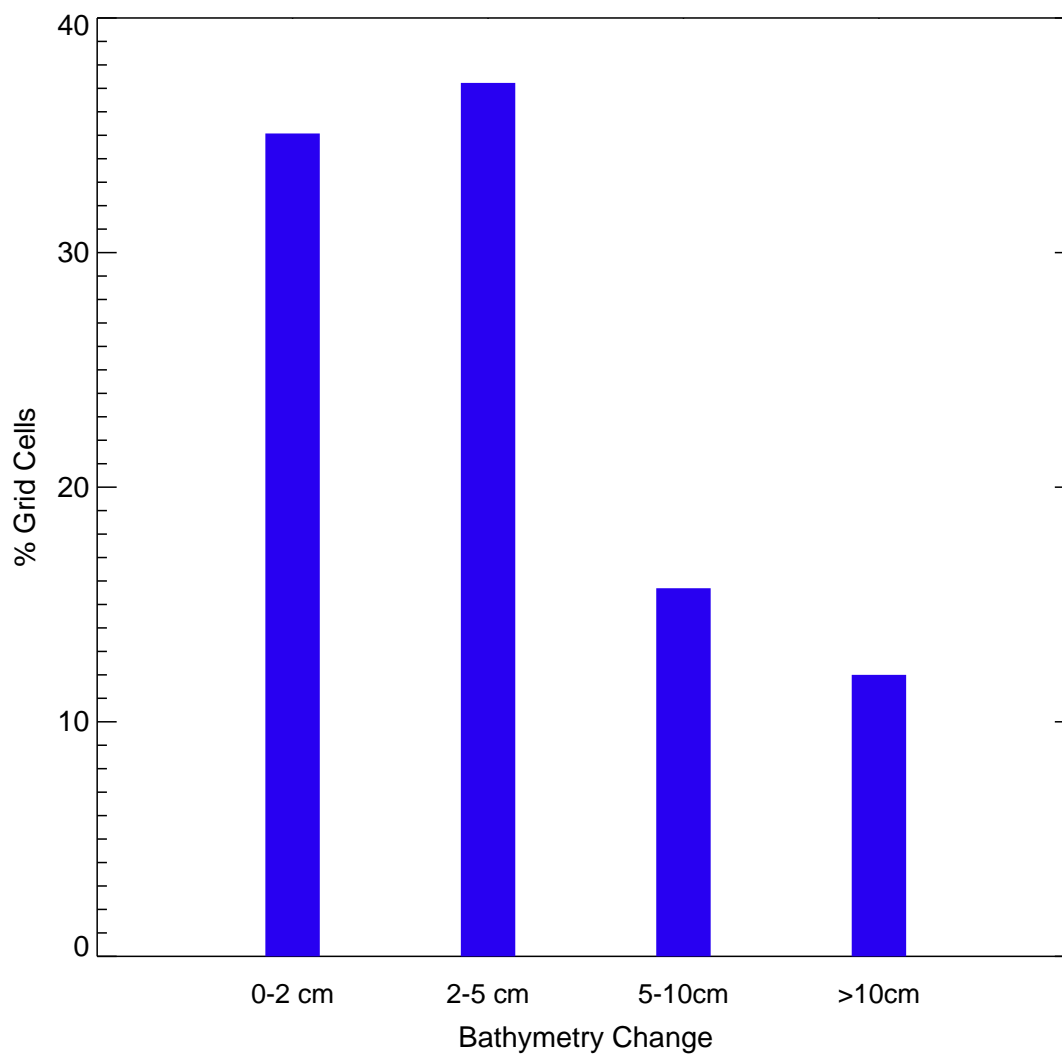


Figure 8

Frequency Distribution of Measured Bathymetric Changes Between WY 2007 and 2008
Exposure Depth Dispute Resolution

*Source: Modified plotting from Figure 67 from Appendix M of the RI report (Anchor QEA et al. 2015).
Bathymetry data averaged over grid cells.*

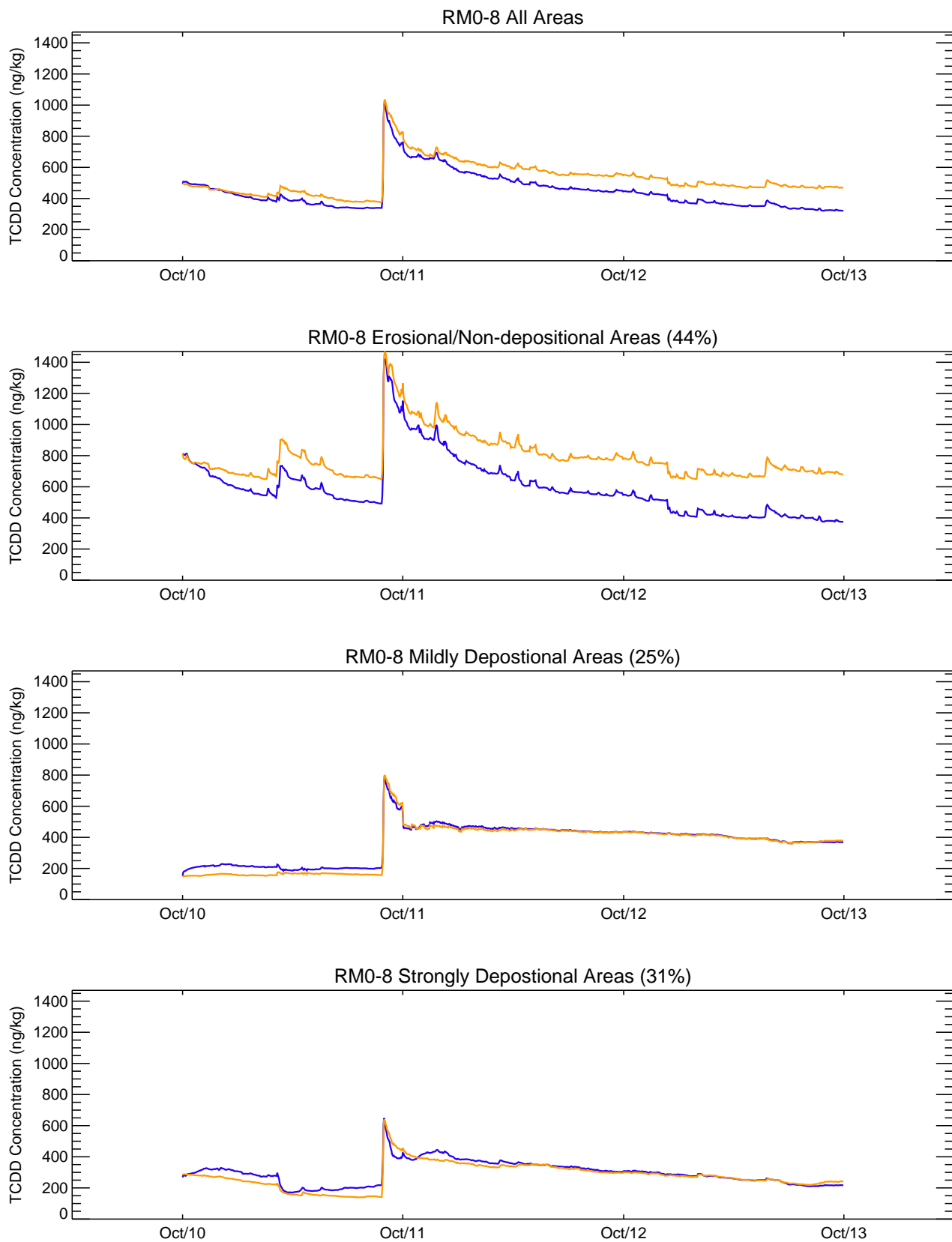


Figure 9

Model Sensitivity Results of 2 cm Sediment 2,3,7,8-TCDD Concentrations in LPR during WY 2011-2013
Exposure Depth Dispute Resolution

— Fluff Sensitivity Run 1
— Base Run

Fluff Sensitivity Run 1: Same as base run except $k_c=0.15$ and $k_f=5000k$.